LANDFILL CAPPING AGENDA

- NFESC (15 minutes)
  - TAT Objectives, Services, Points of Contact
  - Kaneohe Alternative Landfill Cap Project
- GeoSyntec Consultants (1.5 hours)
  - Landfill Closure Systems
    - Regulatory Drivers
    - Final Cap Design
    - Innovative Caps
- Army Corps of Engineers (1.5 hours)
  - Construction Guidelines & QA/QC
  - Landfill Case Studies (Successes & Failures)
  - O&M Issues
  - Cost Analyses/Comparisons

TAT OBJECTIVES & SERVICES

- Innovative Landfill Capping Projects
  - MCBH Kaneohe, HI (Technology Demonstration)
  - MCB Camp Pendleton, CA (Implementation)
- Technical Papers, Posters, Conferences, & Seminars
- Provide Training and Assistance
  - Landfill Capping/Closure Issues
  - Innovative Technologies
  - Technical Library Information
  - Project Contacts and Coordination

POINTS OF CONTACT

(805) 982-0469

(805) 982-1618

(805) 982-1795

(805) 982-2636

Fax:	(805) 982-4304
DSN:	551-ext.
Web Page:	http://www.nfesc.navy.mil

ALTERNATIVE LANDFILL CAPPING

NAVY LANDFILL OPERATIONS

Description:

The Navy has 200+ landfill sites that need a final resolution. Capping is the least expensive way to manage the risk, but it is still expensive. Alternative caps offer the same protection at lower costs compared to EPA caps.

Benefits:

- EPA RCRA C Cap costs $1M / Acre
- EPA RCRA D Cap costs $0.1M / Acre
- Alternative Cap costs $0.05M / Acre

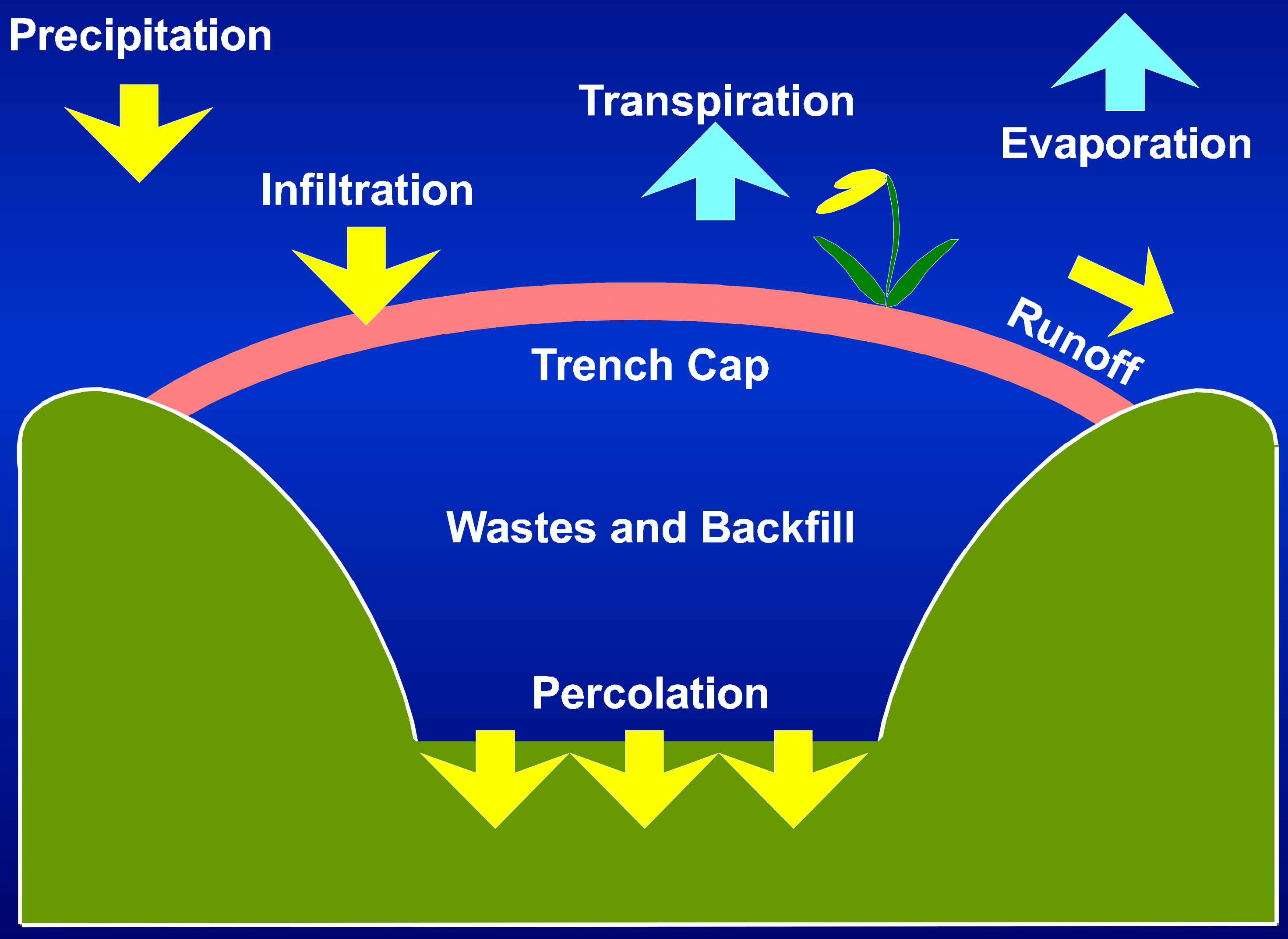
- Evapotranspiration (ET) Cap (Vegetative)
  - Use of native vegetation to consume all water stored in the soil within the plant root zone

–

- Water Harvesting Cap
  - ET cap and impermeable structures to enhance runoff where ET alone is not sufficient

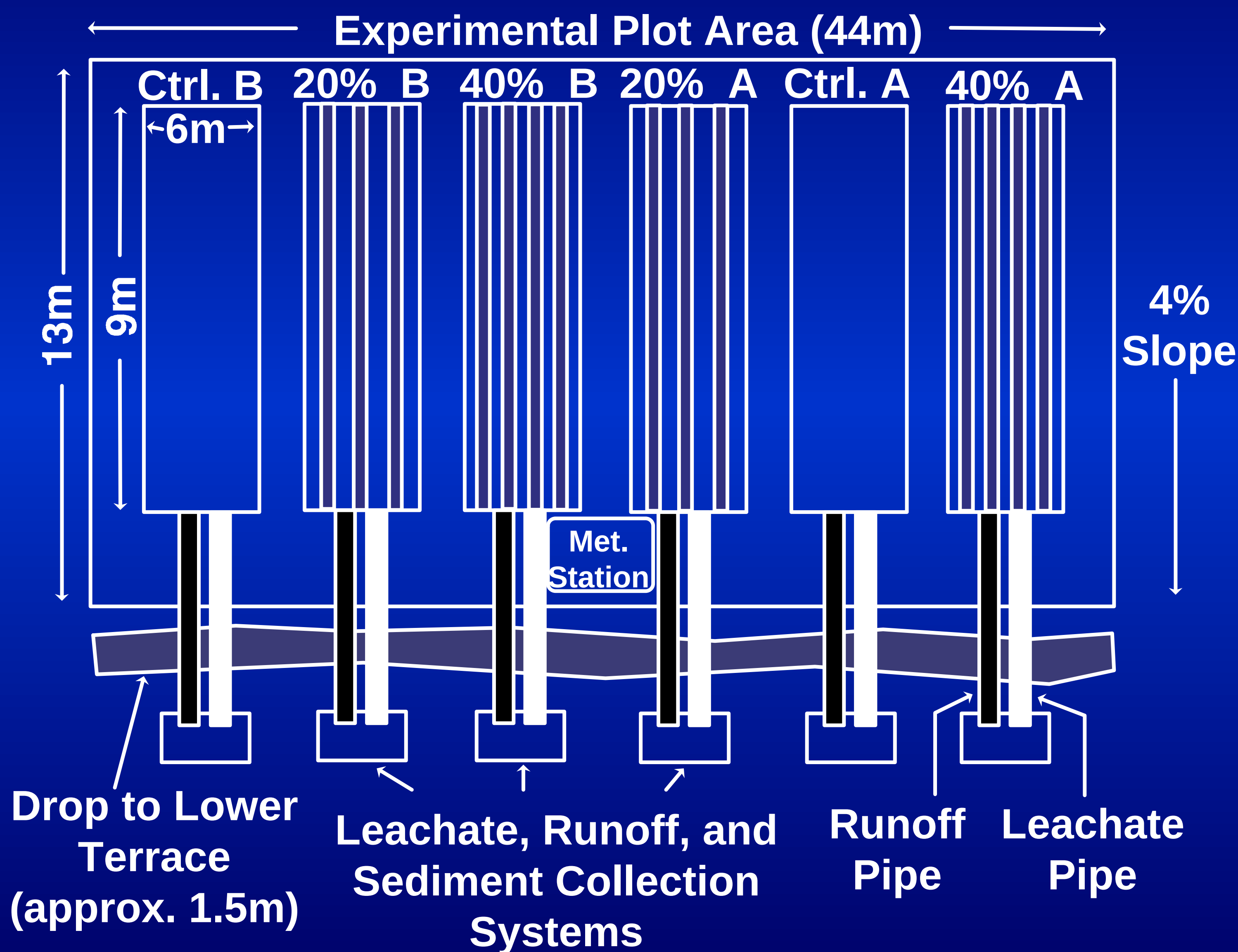
ALTERNATIVE LANDFILL CAPPING

WATER BALANCE



ALTERNATIVE LANDFILL CAPPING

EXPERIMENTAL PLOTS PLAN VIEW

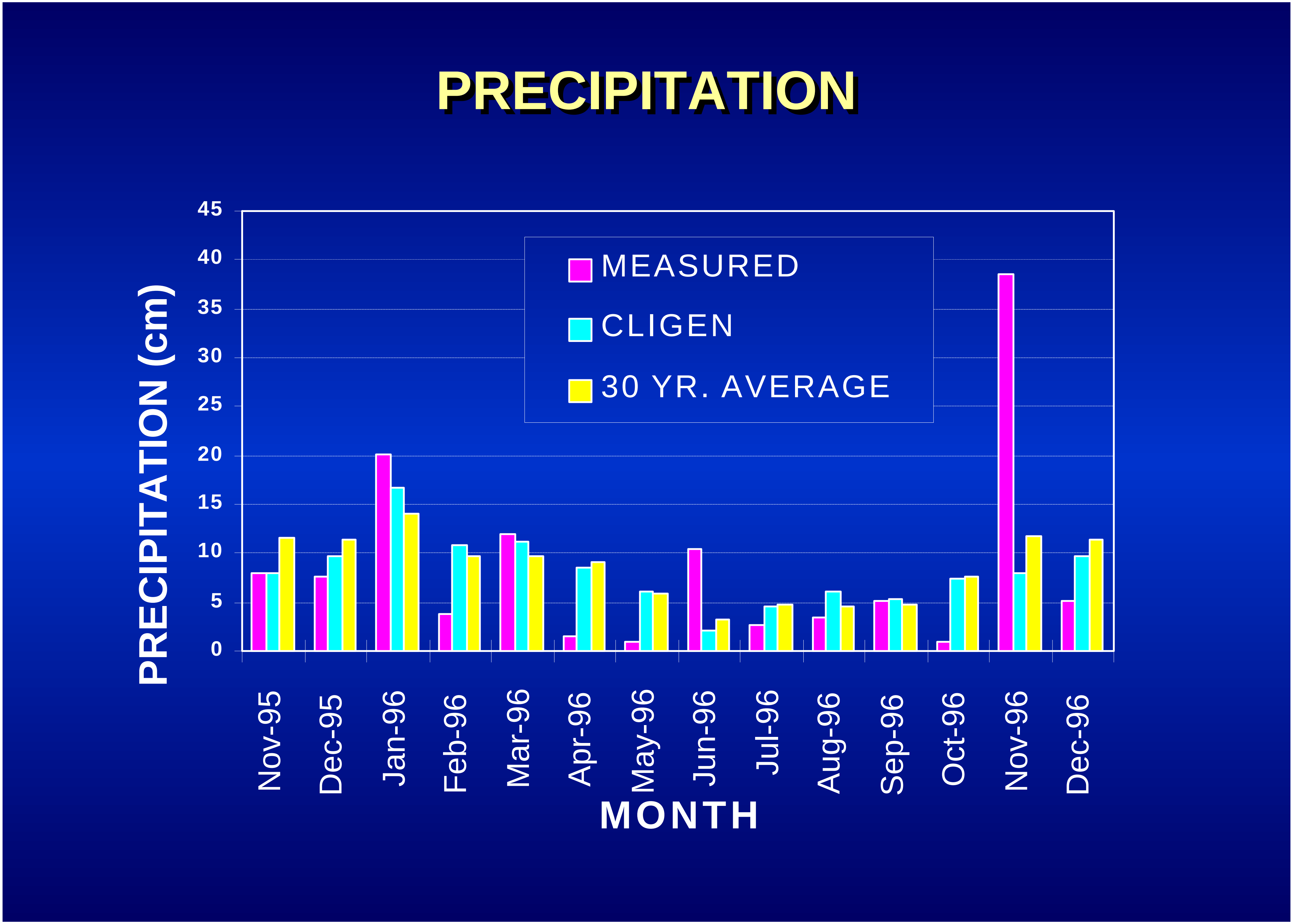


ALTERNATIVE LANDFILL CAPPING

INITIAL PLOT CONSTRUCTION

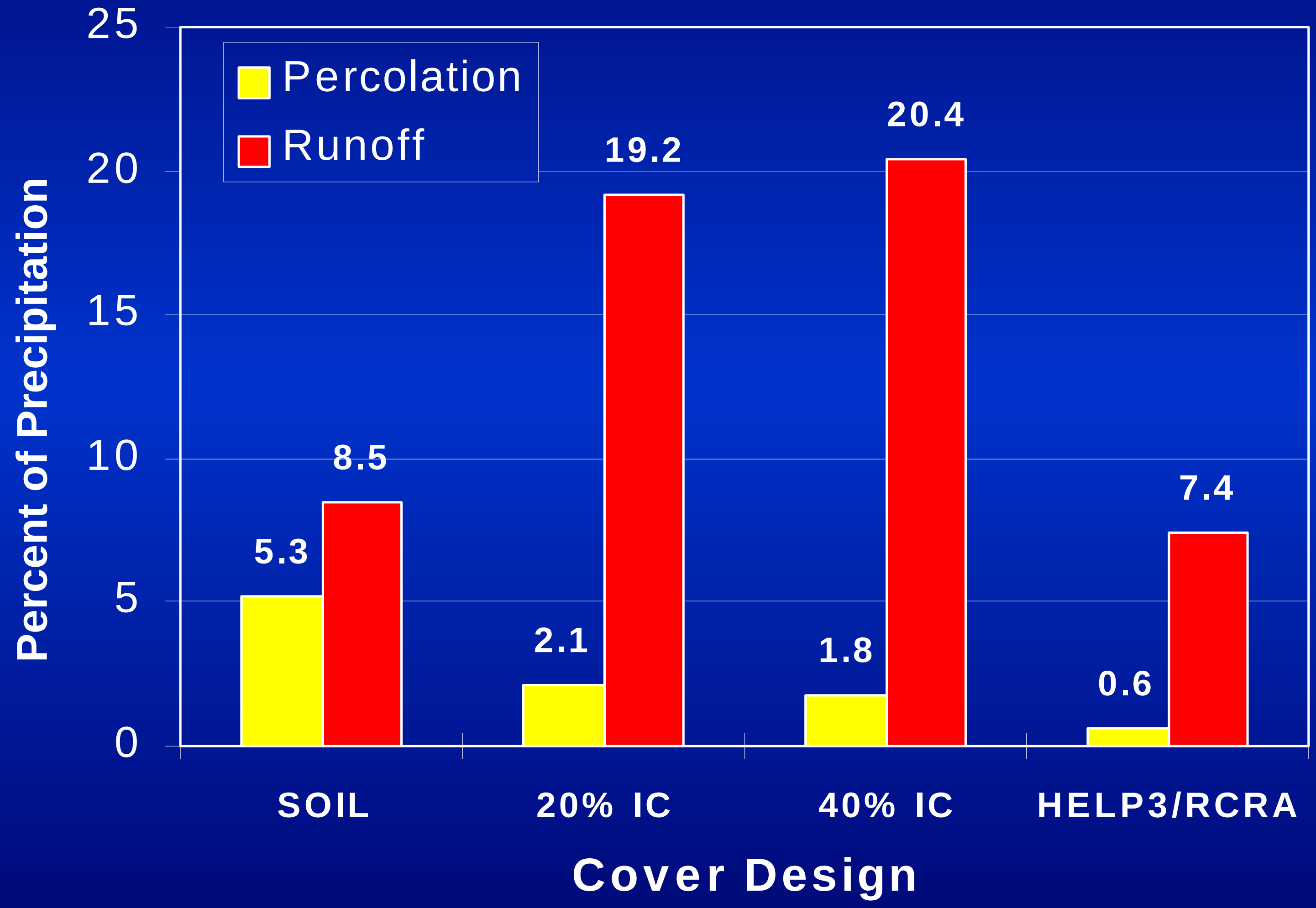
ALTERNATIVE LANDFILL CAPPING

CURRENT VIEW OF TEST PLOTS

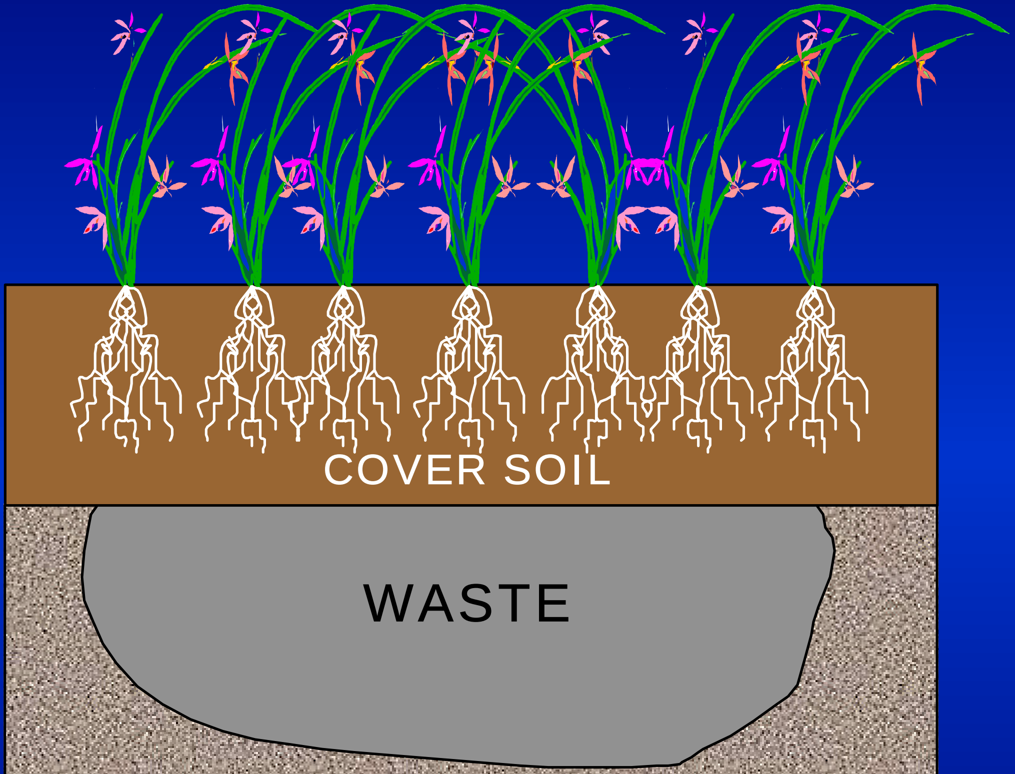


PRECIPITATION
MEASURED
CLIGEN
30 YR. AVERAGE
PRECIPITATION (cm)
0
5
10
15
20
25
30
35
40
45
Nov-95
Dec-95
Jan-96
Feb-96
Mar-96
Apr-96
May-96
Jun-96
Jul-96
Aug-96
Sep-96
Oct-96
Nov-96
Dec-96
MONTH

RELATIVE PERFORMANCE



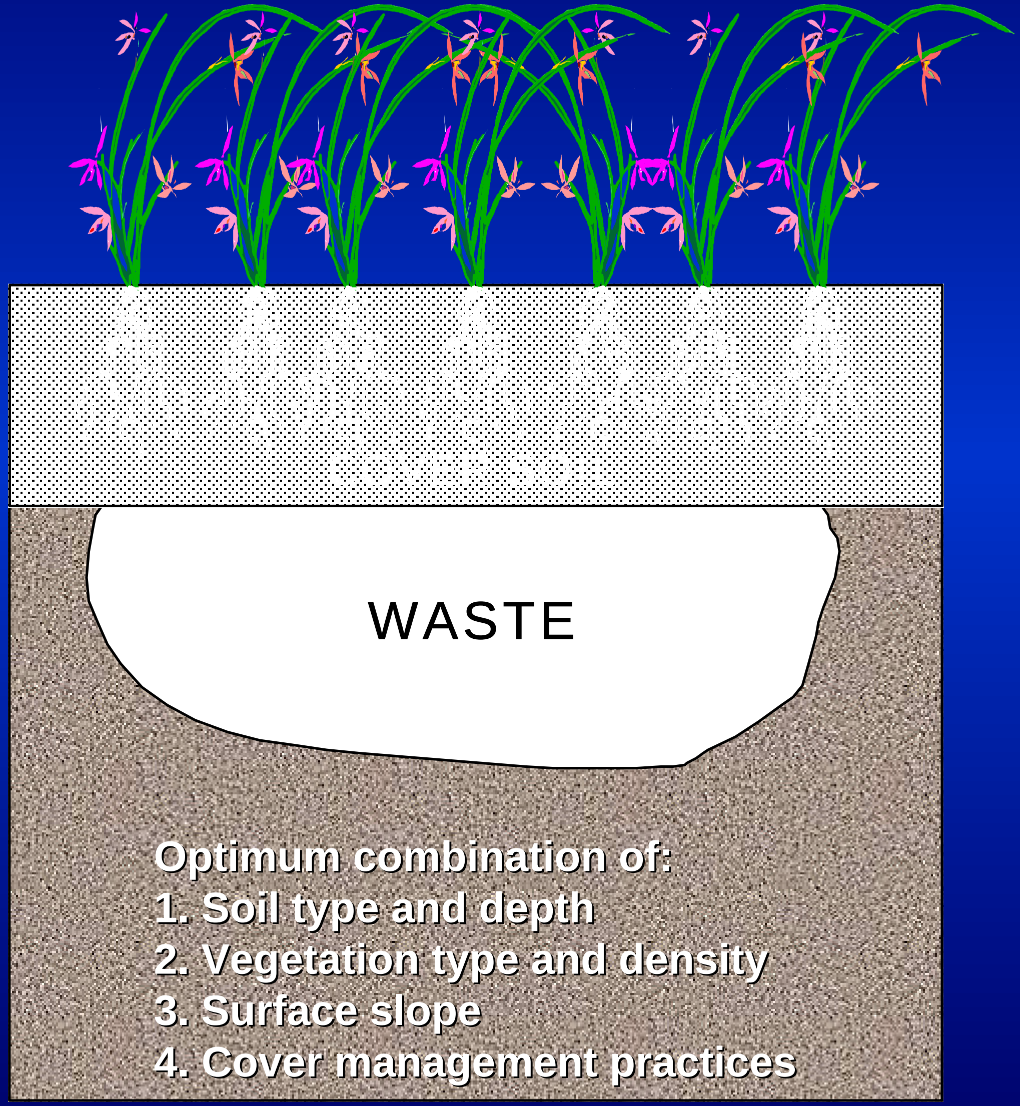
EVAPOTRANSPIRATION COVER DESIGN



Optimum combination of:

1. Soil type and depth
2. Vegetation type and density
3. Surface slope
4. Cover management practices

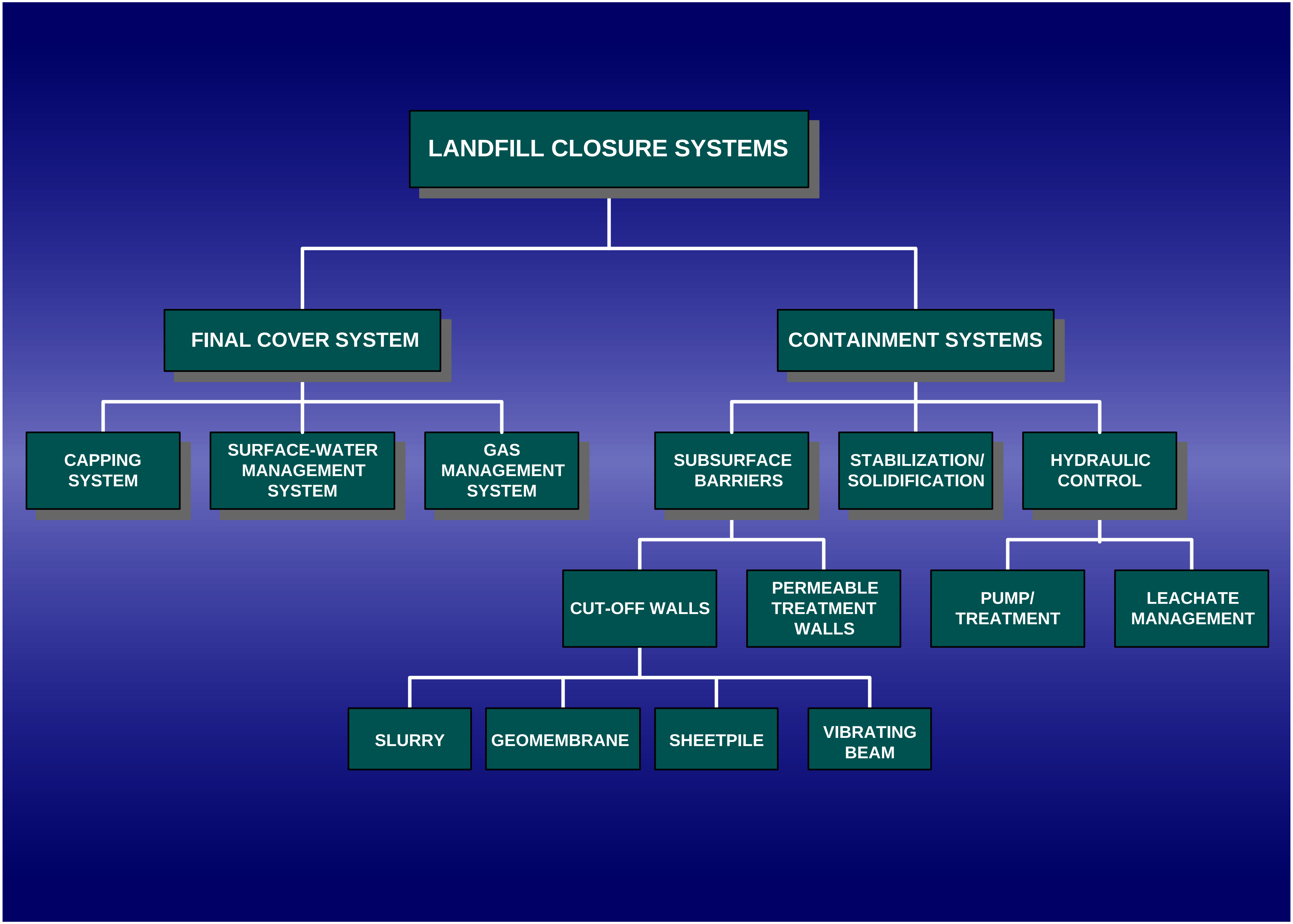
EVAPOTRANSPIRATION COVER DESIGN



SUMMARY AND CONCLUSIONS

- Results support the concept of infiltration control
-
- IC designs increased runoff
-
- IC designs tended to reduce percolation
-
- From 75% up to 98% of the runoff and percolation was generated during 2-4 months
-
- No clear advantage of using 40% runoff enhancement over 20%

LANDFILL CLOSURE SYSTEMS FOR U.S. NAVAL FACILITIES



LANDFILL CLOSURE SYSTEMS
FINAL COVER SYSTEM
CONTAINMENT SYSTEMS
CAPPING SYSTEM
SURFACE-WATER MANAGEMENT SYSTEM
GAS MANAGEMENT SYSTEM
SUBSURFACE BARRIERS
STABILIZATION/ SOLIDIFICATION
HYDRAULIC CONTROL
CUT-OFF WALLS
PERMEABLE TREATMENT WALLS
PUMP/ TREATMENT
LEACHATE MANAGEMENT
SLURRY
GEOMEMBRANE
SHEETPILE
VIBRATING BEAM

LANDFILL COVER SYSTEM SUCCESSES

LANDFILL COVER SYSTEM FAILURES

LANDFILL CLOSURE SYSTEMS

- Functional goals
- Regulatory drivers
- Closure system components
- Design process

FUNCTIONAL GOALS

FUNCTIONAL GOALS
LANDFILL CLOSURE SYSTEMS

- Safe, environmentally-protective, long-term isolation of waste

- Protect human health and environment

- Prevent contaminant migration across all major pathways:
  - Groundwater
  - Surface water
  - Air
  -

–

THIS GOAL IS ACHIEVED THROUGH THE USE OF ENGINEERED COMPONENTS:

FINAL COVER SYSTEM

- Capping system
- Surface-water management system
- Gas management system

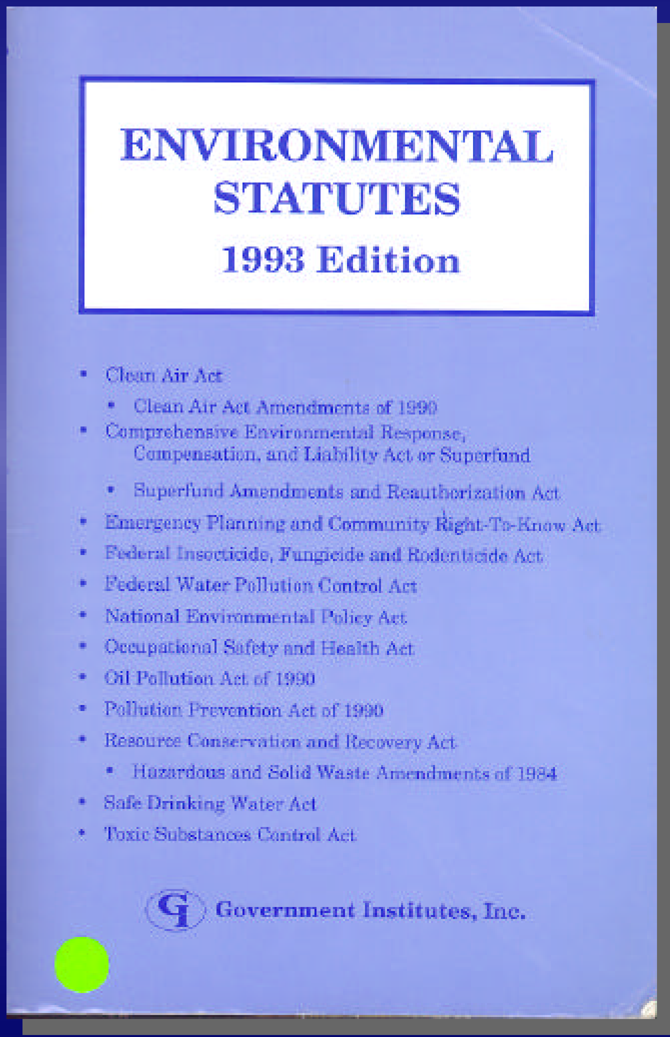
CONTAINMENT SYSTEM

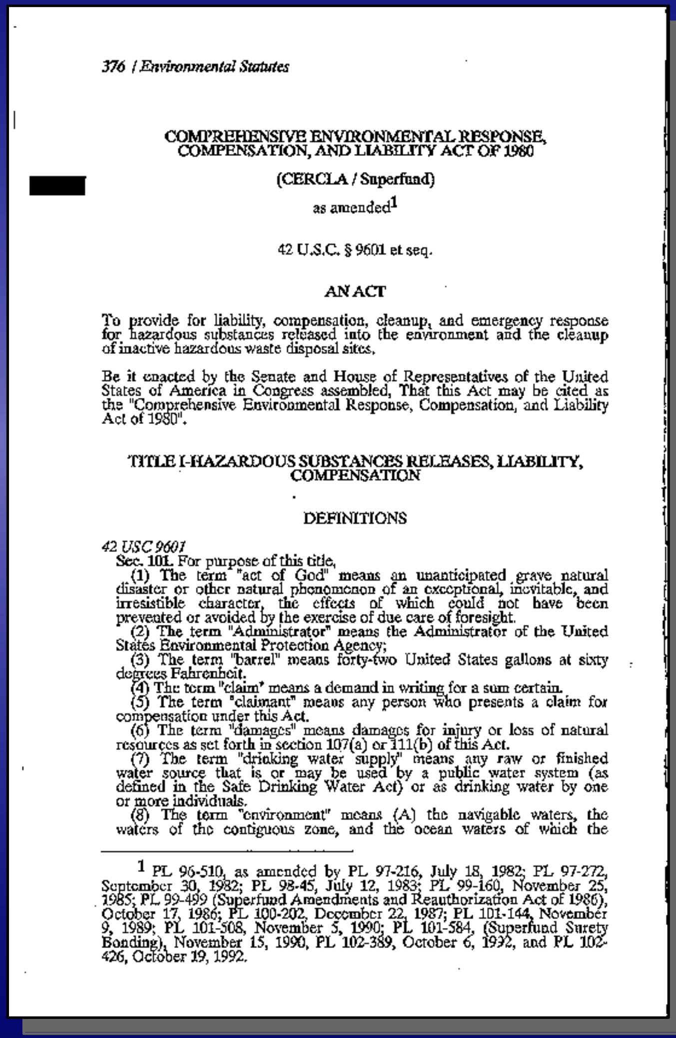
- Subsurface barriers
- In situ stabilization/solidification of the waste
- Hydraulic control

REGULATORY DRIVERS

REGULATORY DRIVERS

ENVIRONMENTAL STATUTES





376 / Environmental Statutes

COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT OF 1980

(CERCLA / Superfund)

as amended[1]

42 U.S.C. § 9601 et seq.

AN ACT

To provide for liability, compensation, cleanup, and emergency response for hazardous substances released into the environment and the cleanup of inactive hazardous waste disposal sites.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That this Act may be cited as the "Comprehensive Environmental Response, Compensation, and Liability Act of 1980".

TITLE I-HAZARDOUS SUBSTANCES RELEASES, LIABILITY, COMPENSATION

DEFINITIONS

42 USC 9601

Sec. 101. For purpose of this title,

(1) The term "act of God" means an unanticipated grave natural disaster or other natural phenomenon of an exceptional, inevitable, and irresistible character, the effects of which could not have been prevented or avoided by the exercise of due care of foresight.

(2) The term "Administrator" means the Administrator of the United States Environmental Protection Agency;

(3) The term "barrel" means forty-two United States gallons at sixty degrees Fahrenheit.

(4) The term "claim" means a demand in writing for a sum certain.

(5) The term "claimant" means any person who presents a claim for compensation under this Act.

(6) The term "damages" means damages for injury or loss of natural resources as set forth in section 107(a) or 111(b) of this Act.

(7) The term "drinking water supply" means any raw or finished water source that is or may be used by a public water system (as defined in the Safe Drinking Water Act) or as drinking water by one or more individuals.

(8) The term "environment" means (A) the navigable waters, the waters of the contiguous zone, and the ocean waters of which the

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[1] PL 96-510, as amended by PL 97-216, July 18, 1982; PL 97-272, September 30, 1982; PL 98-45, July 12, 1983; PL 99-160, November 25, 1985; PL 99-499 (Superfund Amendments and Reauthorization Act of 1986), October 17, 1986; PL 100-202, December 22, 1987; PL 101-144, November 9, 1989; PL 101-508, November 5, 1990; PL 101-584, (Superfund Surety Bonding), November 15, 1990, PL 102-389, October 6, 1992, and PL 102-426, October 19, 1992.

REGULATORY DRIVERS

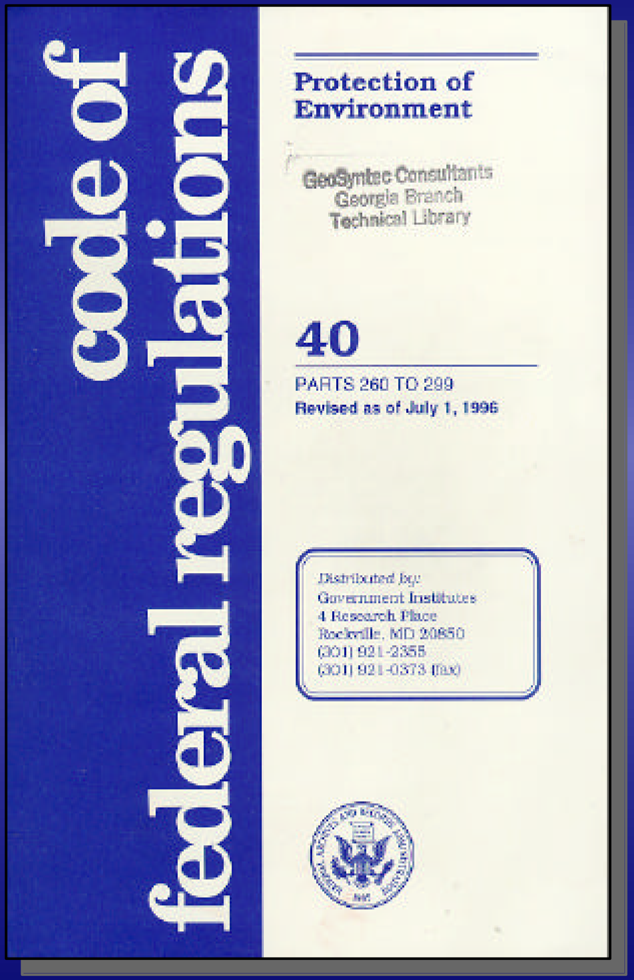
FEDERAL RULES

Comprehensive Emergency Response, Compensation, and Liability Act (CERCLA)

- **40 CFR - 300.415 (Removal Action)**
- **40 CFR - 300.435 (Remedial Action)**

Resource Conservation and Recovery Act (RCRA)

- **40 CFR - 258 (MSW Landfills)**
- **40 CFR - 264 (Hazardous Waste TSDF)**
- **40 CFR - 265 (Interim Status Facilities)**



REGULATORY DRIVERS

STATE-LED PROGRAMS

Department of Environmental Conservation

Division of Solid Waste

6 NYCRR Part 360
Solid Waste
Management Facilities

Revisions/Enhancements to New York State's Solid Waste Management Facilities

Effective October 9, 1993

New York State Department of Environmental Conservation
MARIO M. CUOMO, Governor THOMAS C. JORLING, Commissioner

SUBPART 360-2

LANDFILLS

Section 360-2.1 Applicability.

This Subpart regulates the siting, design, construction, operation, closure, and post-closure activities including, if necessary, corrective action of all new landfills, landfills existing on the effective date of this Part, and lateral or vertical expansions of landfills that dispose of solid waste other than those regulated under Subpart 360-7 and section 360-8.6 of this Part (however subdivision 360-2.14(a) and paragraph 360-2.14(b)(1) of this Part do not apply to landfills constructed or operated in Nassau or Suffolk County. Landfills in Nassau and Suffolk Counties are also subject to the requirements set forth in Subpart 360-8 of this Part). Liquid storage facilities as part of a landfill application must be designed, constructed, operated and closed in accordance with the provisions of Subpart 360-6 of this Part. The requirements for the construction and operation of landfill gas recovery facilities are specified under the provisions of section 360-2.16 of this Part. The provisions for the design of a monofill used for the disposal of ash from solid waste incinerators are addressed in section 360-2.14 of this Subpart. Subsequent landfill development (phased landfill construction beyond the initial permitted phase of construction but that which is entitled by permit) must demonstrate compliance with the design, construction, operation and closure requirements pursuant to the Part 360 regulations in effect at the time of subsequent development. This demonstration must also include a seismic analysis demonstrating compliance with the provisions of paragraph 360-2.7(b)(7) of this Subpart and an estimate of the expected quantity of leachate to be generated from the subsequent portion of the landfill proposed for development pursuant to the provisions of paragraph 360-2.7(b)(9) of this Subpart. The need for additional leachate storage capacity beyond that which was initially constructed must be assessed as a result of this leachate generation estimation.

Section 360-2.2 Transition.

The transition requirements for construction, operation and closure of landfills subject to regulation under this Subpart are set forth in paragraph 360-1.7(a)(3) of this Part. Transition requirements for landfills in existence on the effective date of this Part that accept solid waste incinerator ash residue are also set forth in paragraph 360-3.5(g)(5) of this Part.

LANDFILLS

- **Subtitle C**

  An area of land or an excavation where hazardous wastes are placed for permanent disposal

- **Subtitle D**

  A discrete area of land or an excavation that receives household waste, commercial solid waste, nonhazardous sludge, and industrial solid waste

- **Landfills are not land application units, surface impoundments, injection wells, or waste piles as defined in 40 CFR - 257.2**

REGULATORY DRIVERS

PRESUMPTIVE REMEDIES

- Initiative to Accelerate Cleanup Programs
-
- Preferred Technologies Based on Past Experience
-
- Types
  - Volatile Organic Compounds in Soils
  - Wood Treaters
  - Municipal Landfills
  - Contaminated Groundwater

PRESUMPTIVE REMEDIES

CLEANUP PROCESS IMPACT

- Focus the site evaluation and field investigation
- Streamline the identification of objectives and alternatives
- Eliminate need to compare technologies
- Expedite Record of Decision issuance and preparation of remedial plans

CLOSURE SYSTEM COMPONENTS

CLOSURE SYSTEM COMPONENTS

FINAL COVER SYSTEM

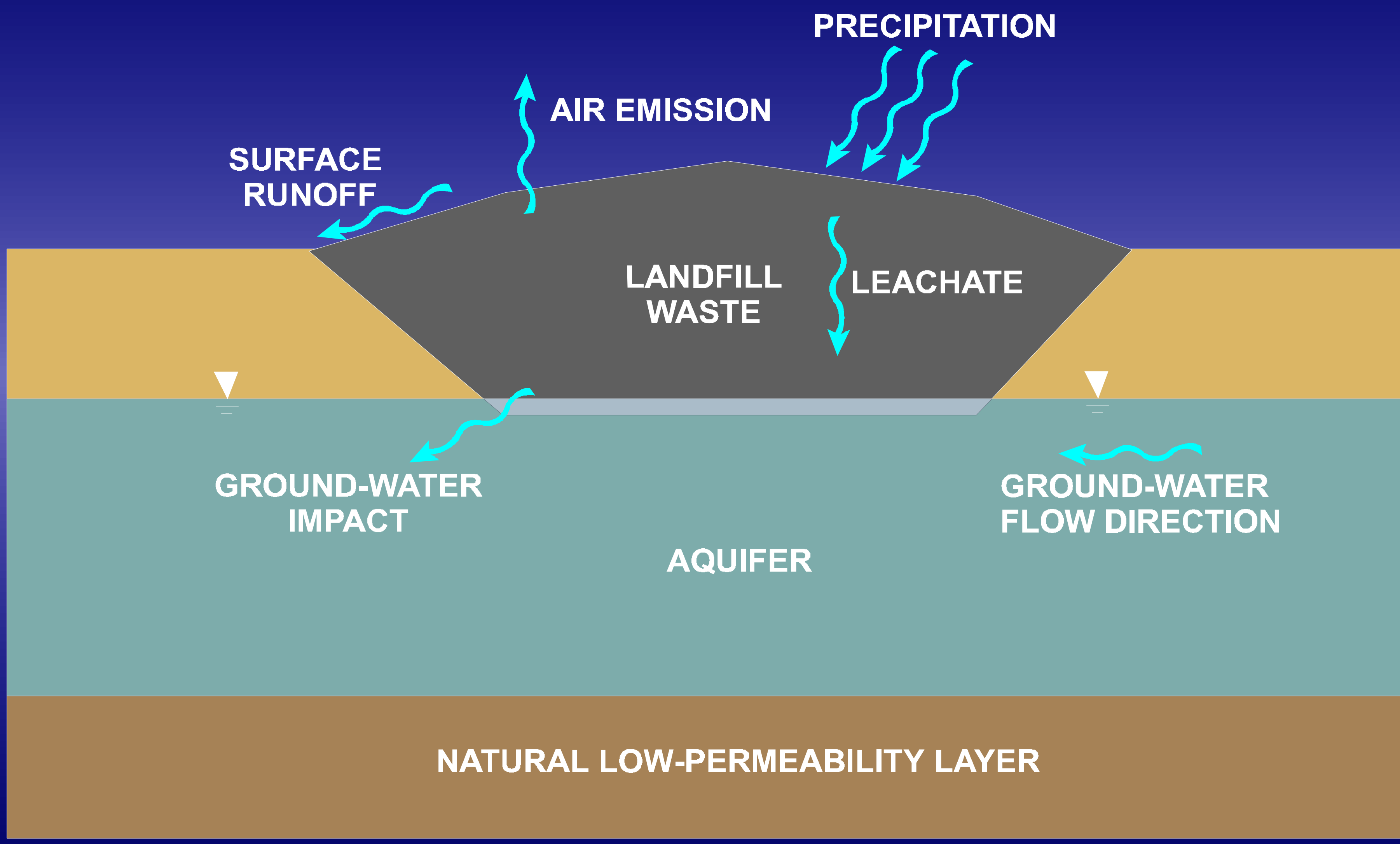
- Capping system
- Surface-water management system
- Gas management system

CONTAINMENT SYSTEM

- Subsurface barriers
- In situ stabilization/solidification of the waste
- Hydraulic control

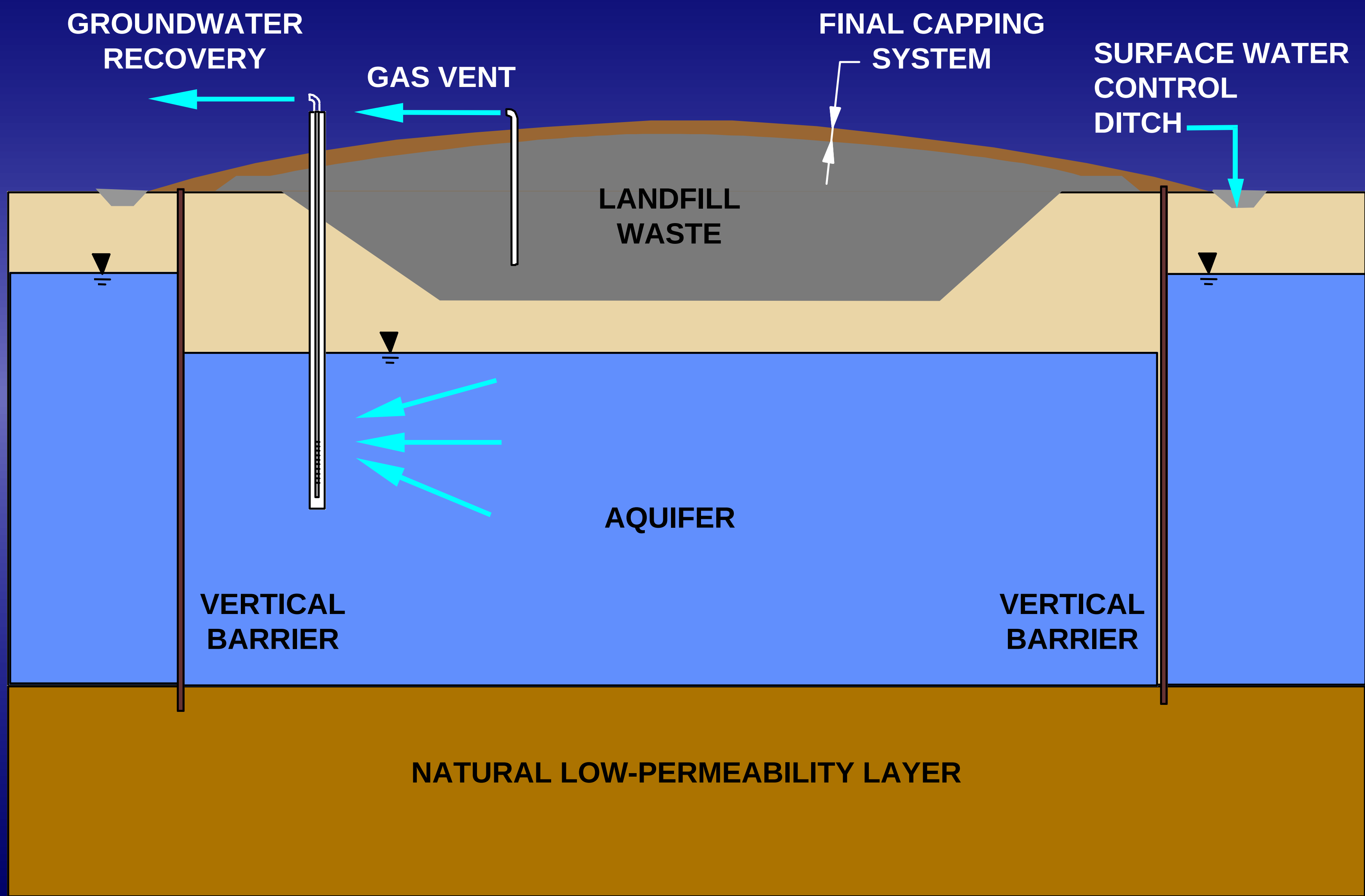
CLOSURE SYSTEM COMPONENTS

LANDFILL EXISTING CONDITIONS



CLOSURE SYSTEM COMPONENTS

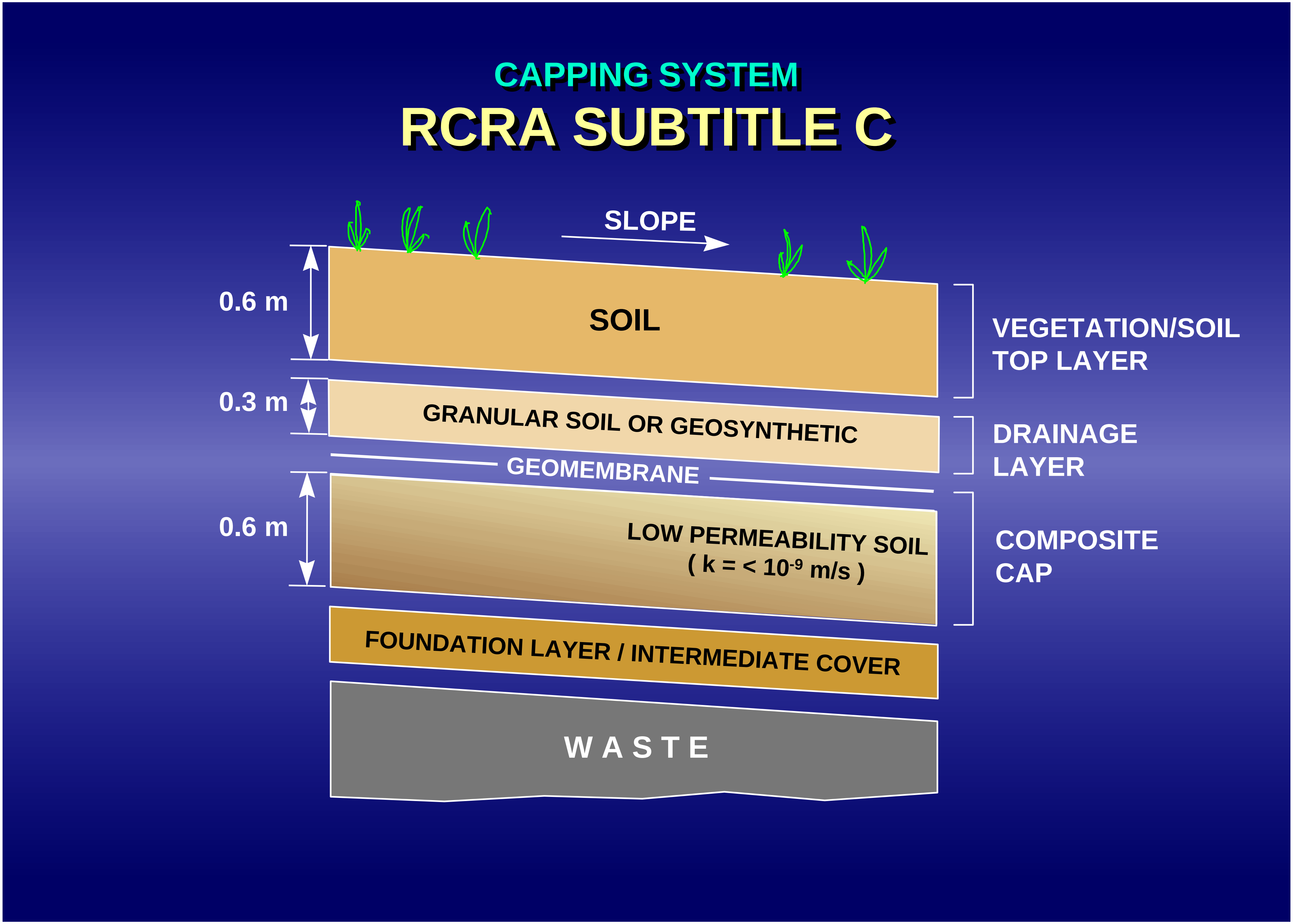
LANDFILL CLOSURE COMPONENTS



CLOSURE SYSTEM COMPONENTS

CAPPING SYSTEM

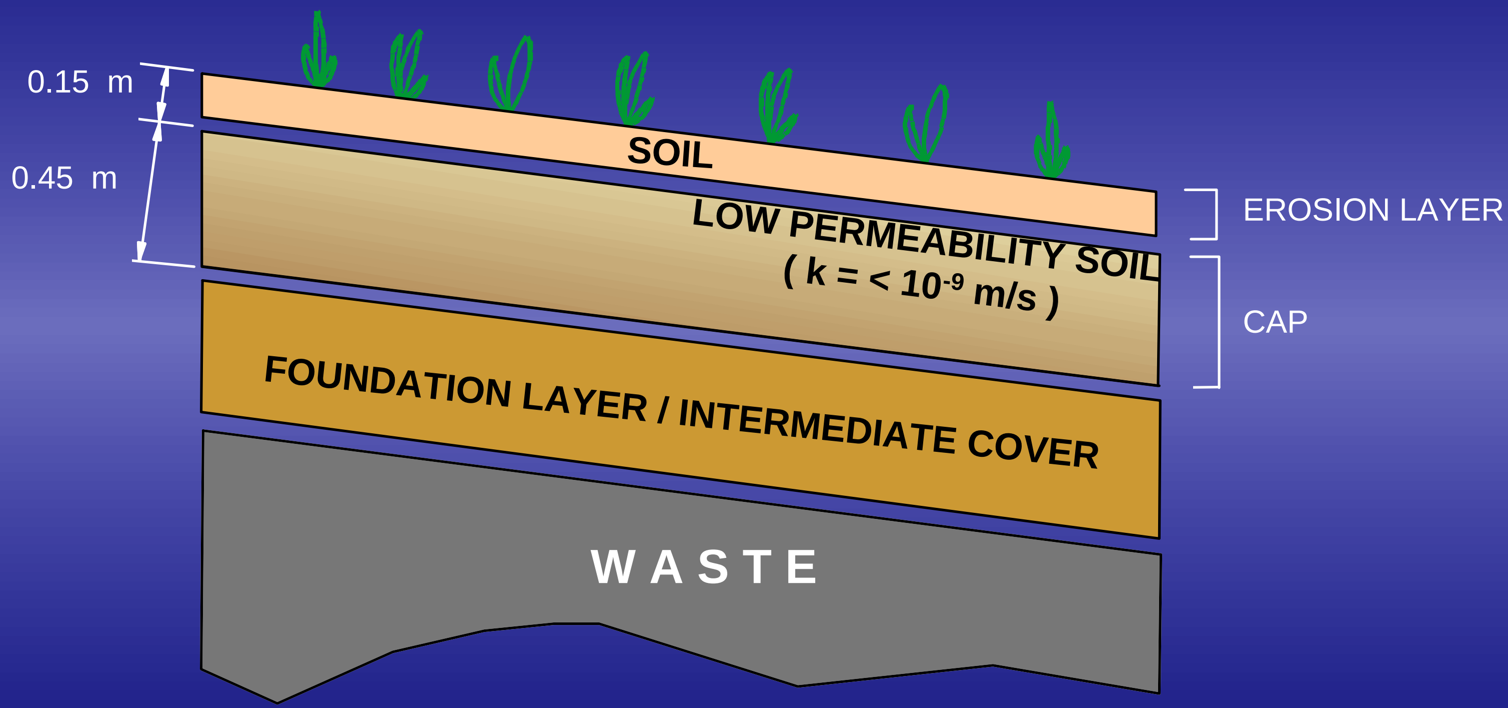
- Combination of one or more drainage layers and low-permeability barrier layers (i.e., caps)
- Cap prevents water infiltration into surface or subsurface contaminant source area
- Drainage layer above cap controls hydraulic head on cap and minimizes downslope seepage forces in the cover soil
- Grass and topsoil layer is usually the topmost layer; function is to limit erosion and promote surface-water runoff



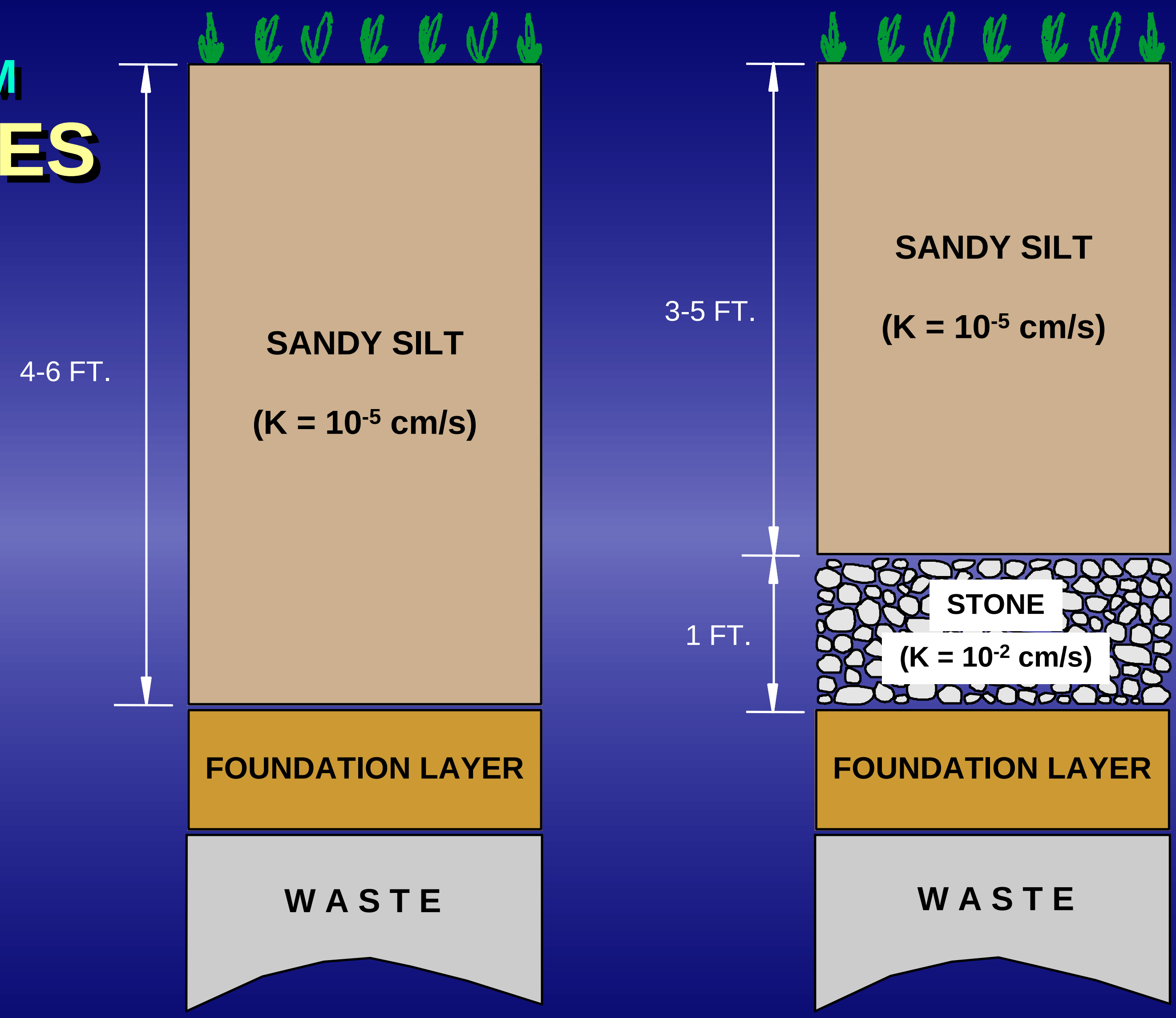
CAPPING SYSTEM
RCRA SUBTITLE C
SLOPE
0.6 m
SOIL
VEGETATION/SOIL TOP LAYER
0.3 m
GRANULAR SOIL OR GEOSYNTHETIC
DRAINAGE LAYER
GEOMEMBRANE
0.6 m
LOW PERMEABILITY SOIL
(k = < 10-9 m/s)
COMPOSITE CAP
FOUNDATION LAYER / INTERMEDIATE COVER
WASTE

CAPPING SYSTEMS

RCRA SUBTITLE D



CAPPING SYSTEM
ALTERNATIVES



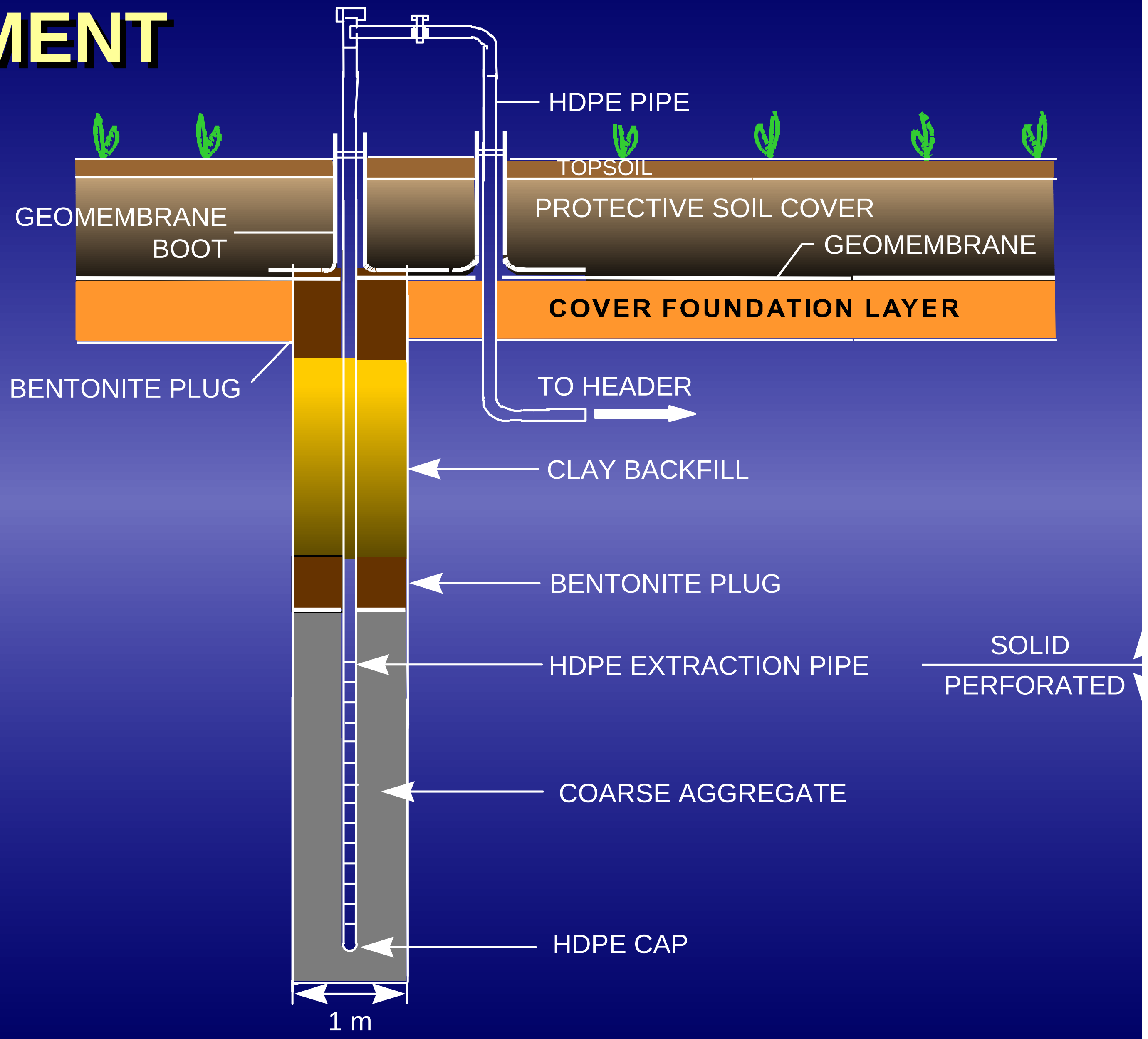
MONOLAYER CAP

CAPILLARY BREAK CAP

DAVIS LIQUID SUPERFUND SITE

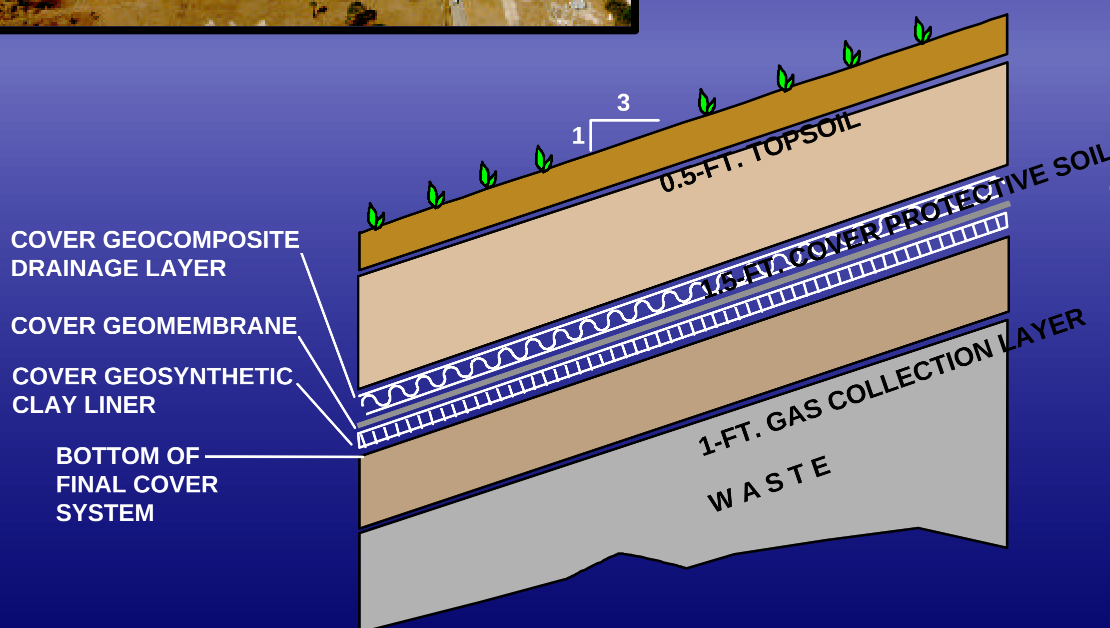
CLOSURE SYSTEM COMPONENTS

GAS MANAGEMENT SYSTEM

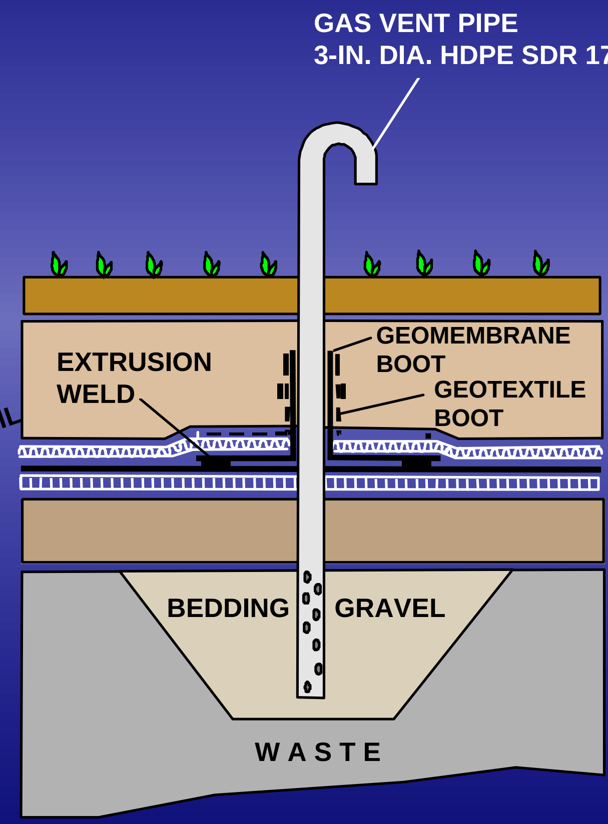


CLOSURE SYSTEM COMPONENTS

GEORGIA SUPERFUND SITE



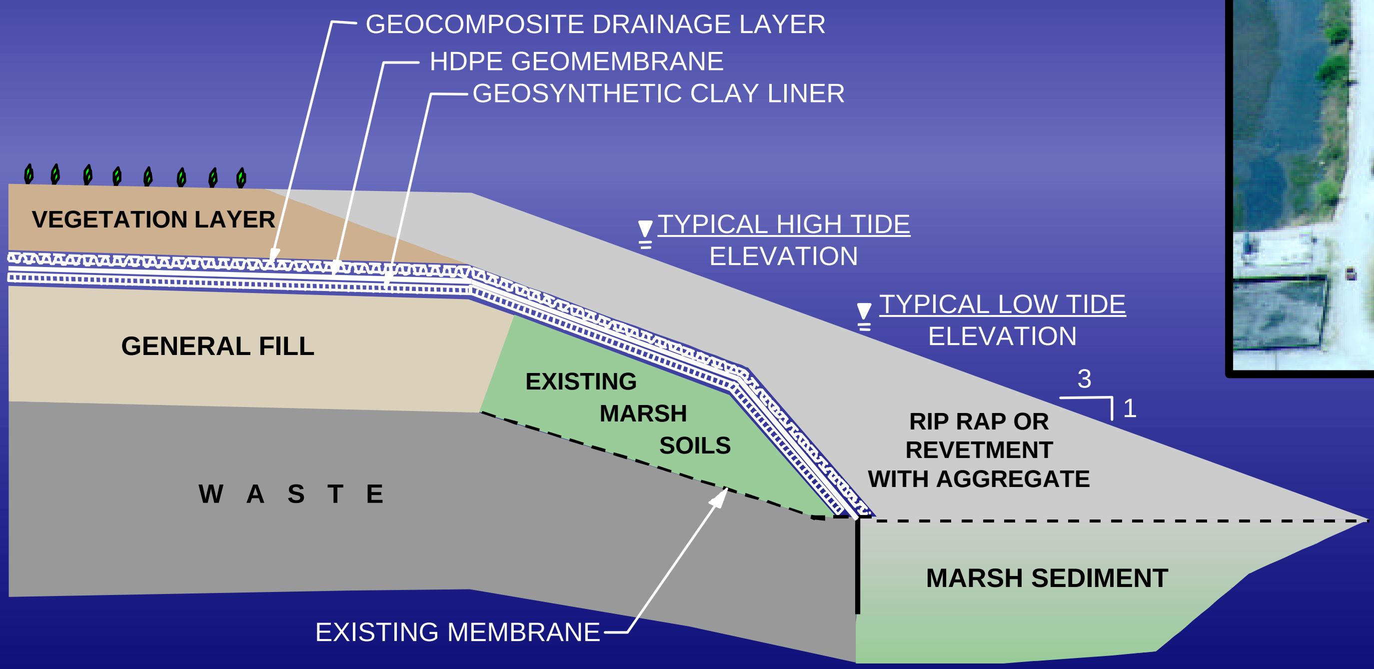
FINAL COVER SYSTEM DETAIL



GAS VENT DETAIL

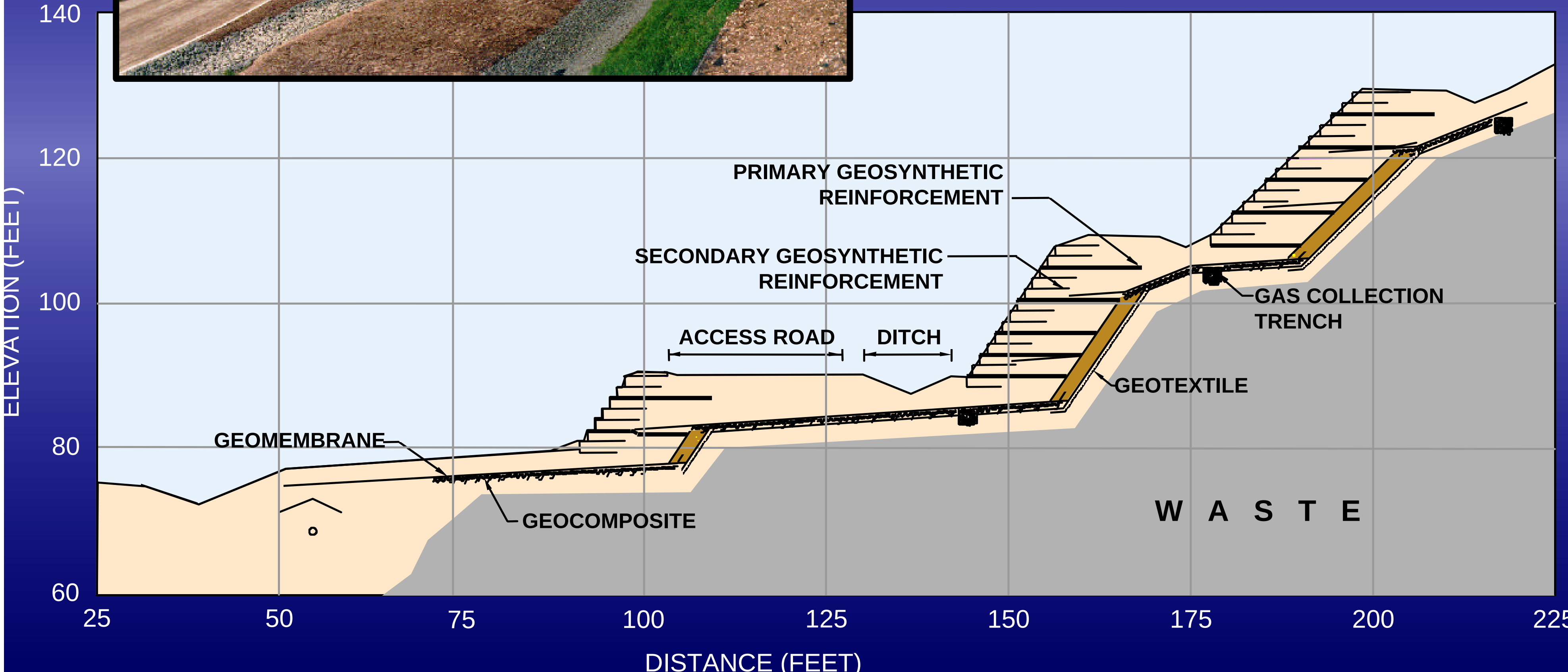
CLOSURE SYSTEM COMPONENTS

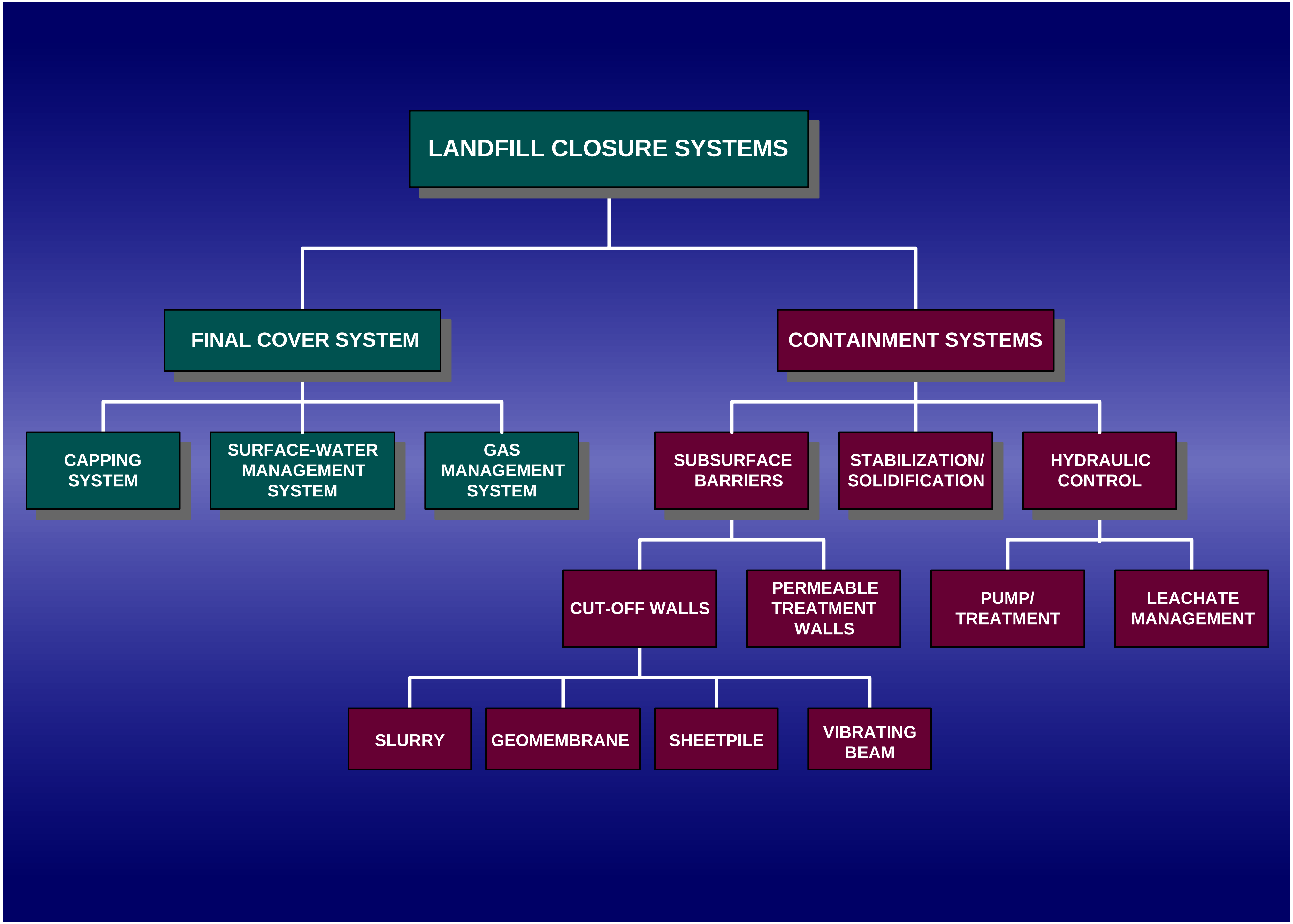
TEXAS SUPERFUND SITE



CLOSURE SYSTEM COMPONENTS

NEW YORK LANDFILL SITE





LANDFILL CLOSURE SYSTEMS
FINAL COVER SYSTEM
CONTAINMENT SYSTEMS
CAPPING SYSTEM
SURFACE-WATER MANAGEMENT SYSTEM
GAS MANAGEMENT SYSTEM
SUBSURFACE BARRIERS
STABILIZATION/ SOLIDIFICATION
HYDRAULIC CONTROL
CUT-OFF WALLS
PERMEABLE TREATMENT WALLS
PUMP/ TREATMENT
LEACHATE MANAGEMENT
SLURRY
GEOMEMBRANE
SHEETPILE
VIBRATING BEAM

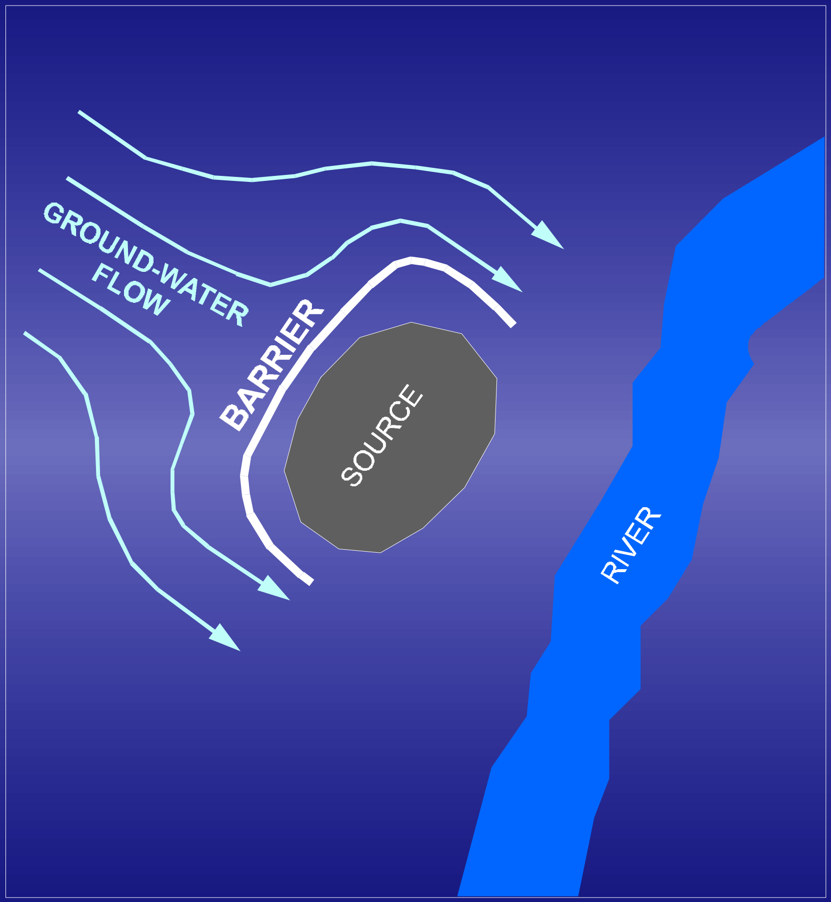
CLOSURE SYSTEM COMPONENTS

SUBSURFACE BARRIERS

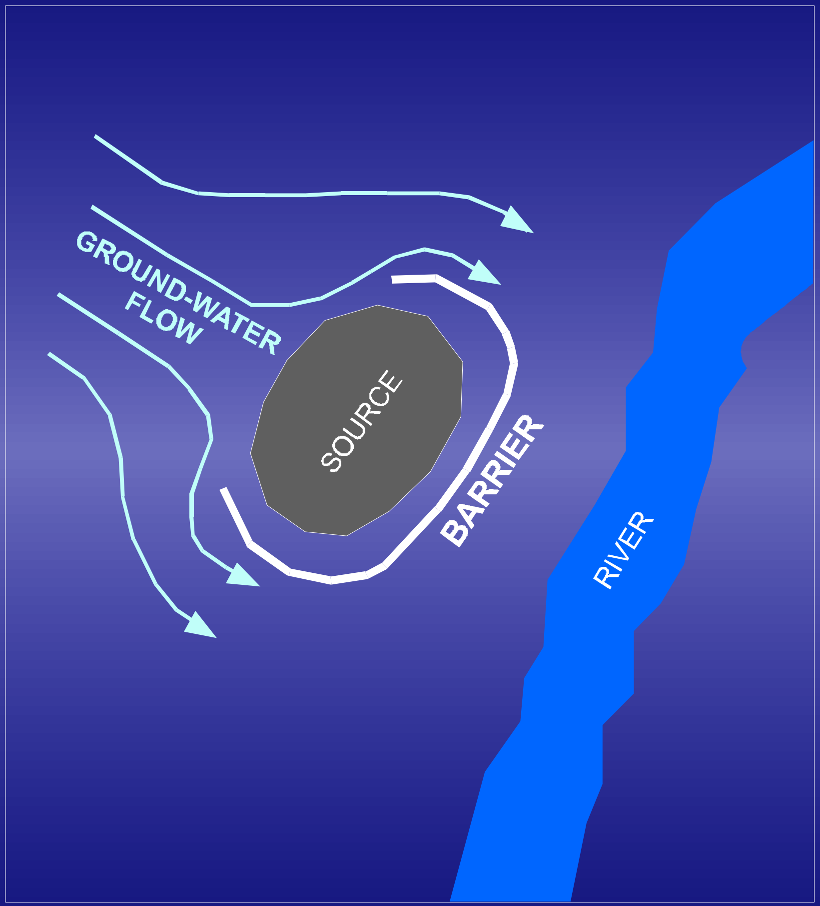
- Cutoff walls are low-permeability structures to provide a barrier to flow of groundwater toward or away from a contaminant source
-
- Permeable treatment walls incorporate a flow-through section to provide contact between contaminated groundwater and treatment media
-

SUBSURFACE BARRIERS

UPGRADIENT



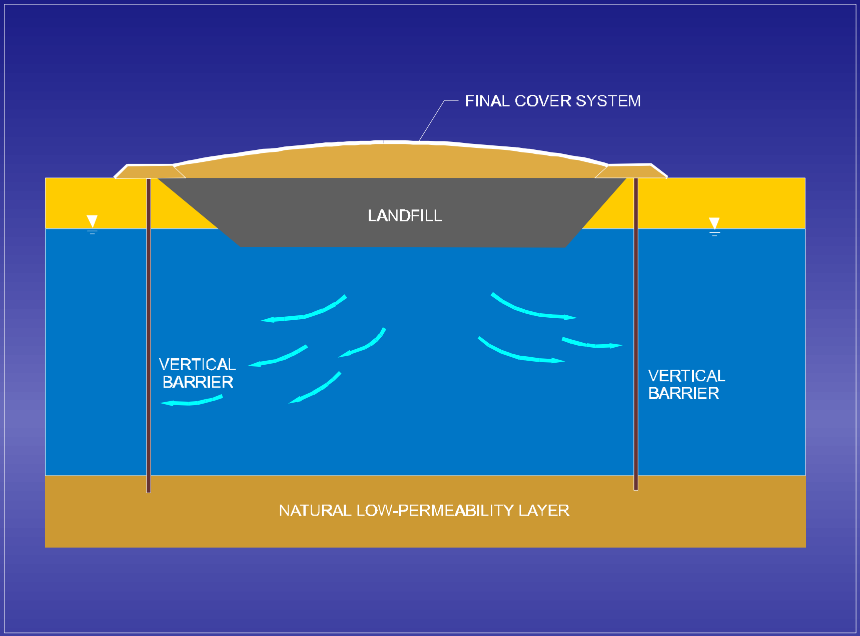
DOWNGRADIENT



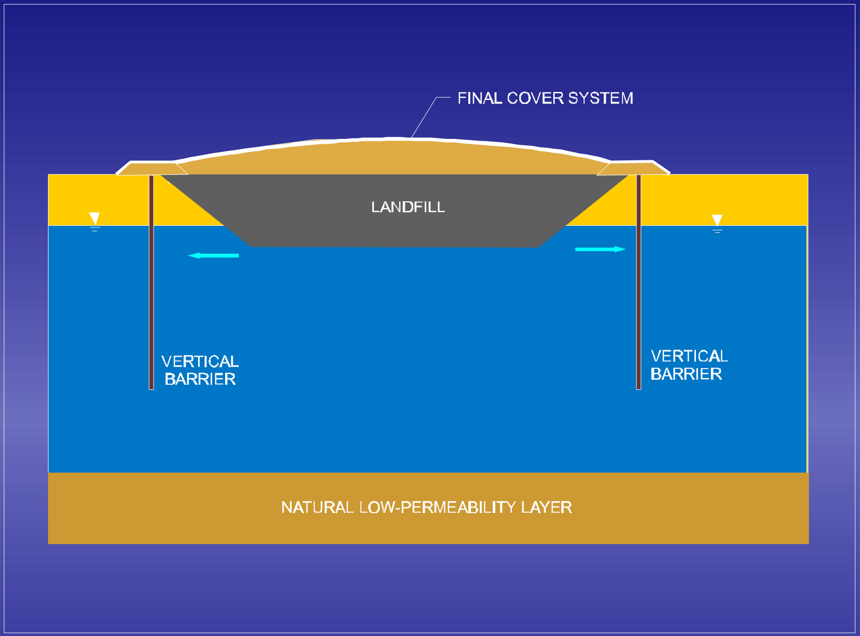
- ✓ Prevents ground water from infiltrating into a source area
- ✓ Prevents migration of contaminated ground water (or gas) from a source area

SUBSURFACE BARRIERS

FULLY PENETRATING



PARTIALLY PENETRATING



- Utilize when complete containment is needed
- Utilize for DNAPL containment
- Utilize with gradient control systems (ground-water extraction within the contained area)

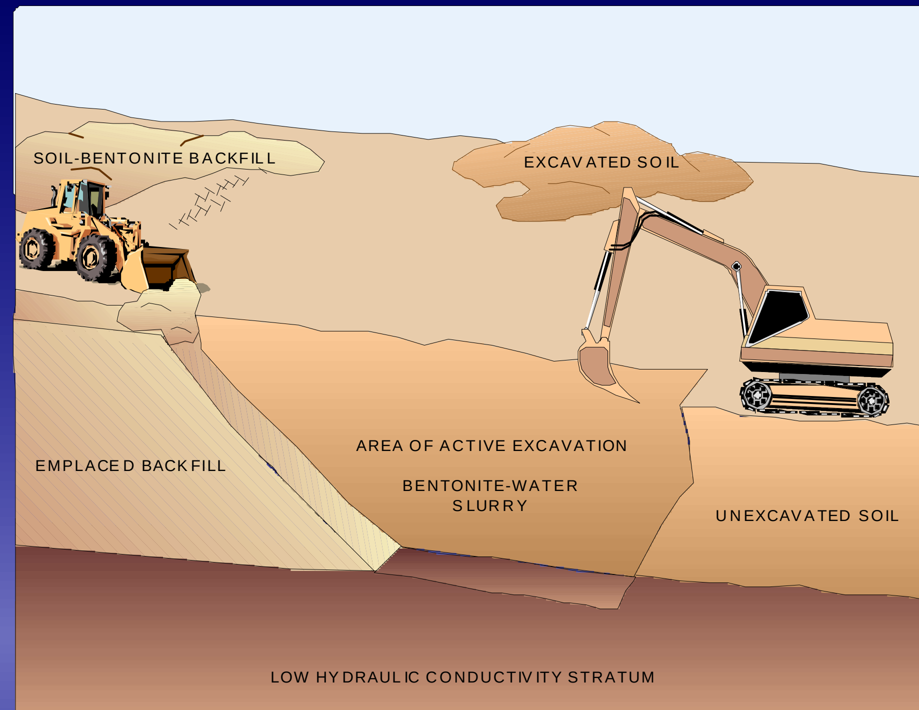
- Utilize with LNAPL remediation
- Utilize when low-permeability layer is at great depth

SUBSURFACE BARRIERS

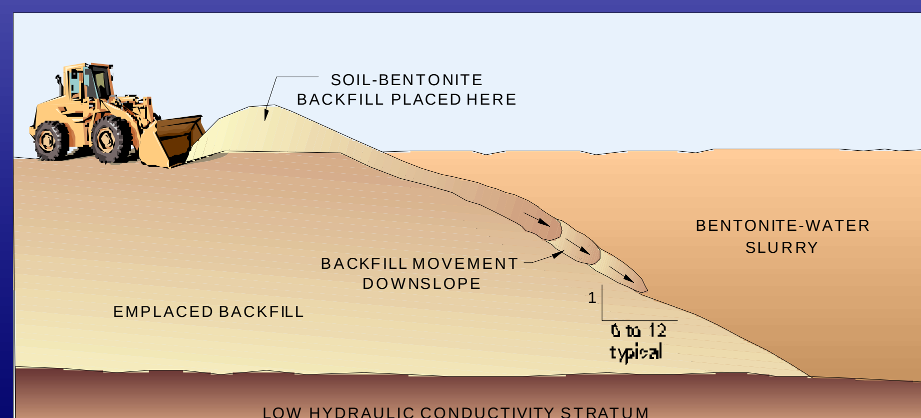
SOIL-BENTONITE WALL CONSTRUCTION

KEY ATTRIBUTES

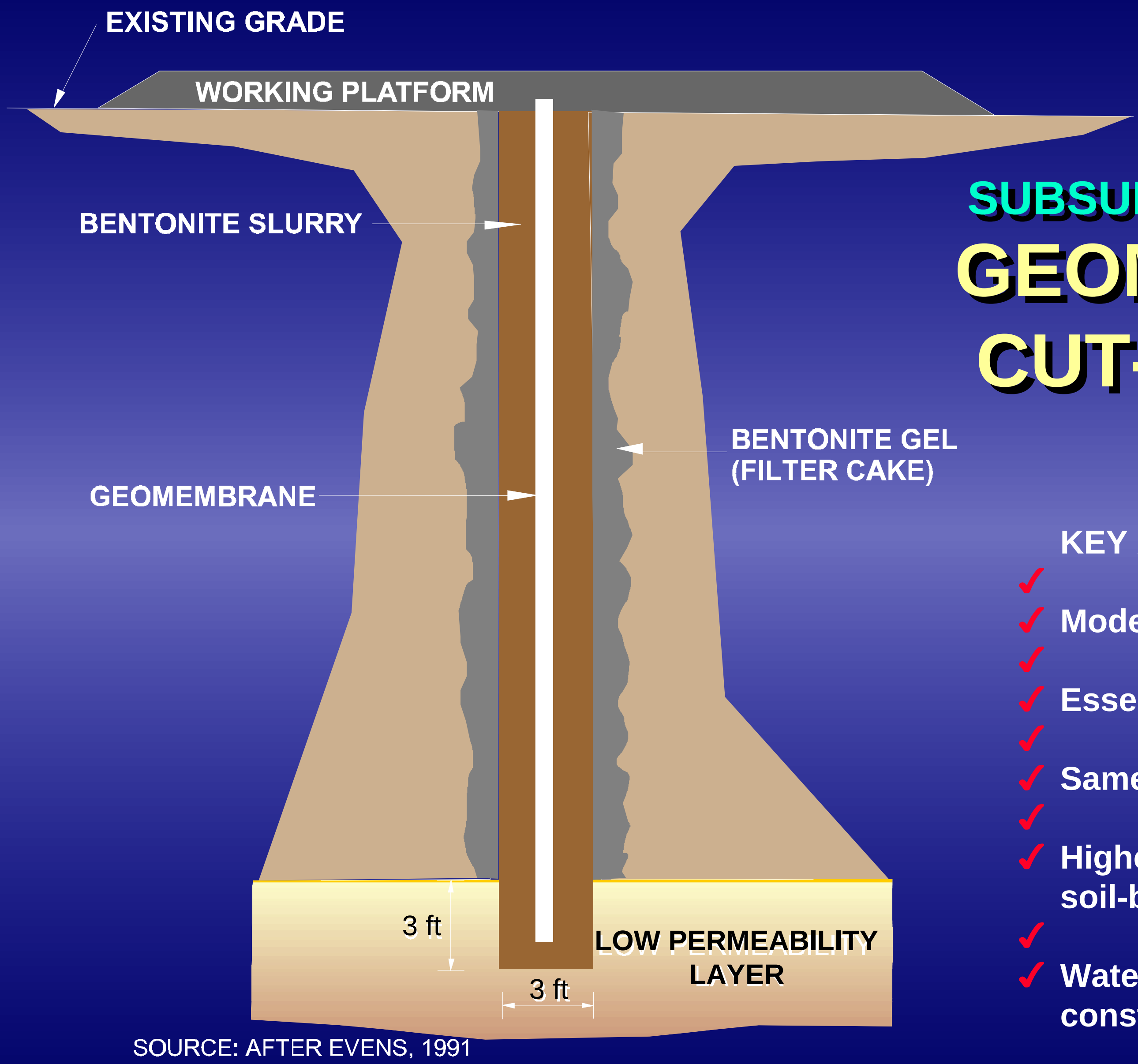
- Least expensive, reliable, versatile
- Provides low (k 10^{-6} to 10^{-7} cm/s) permeability barrier
- Potential issues related to air emissions and contaminated soil disposal
- Requires horizontal ground and significant right-of-way
- Potential negative ground stability impacts
- Requires specialty contractor



SOIL-BENTONITE WALL CONSTRUCTION



SOIL-BENTONITE WALL BACKFILLING



SUBSURFACE BARRIERS

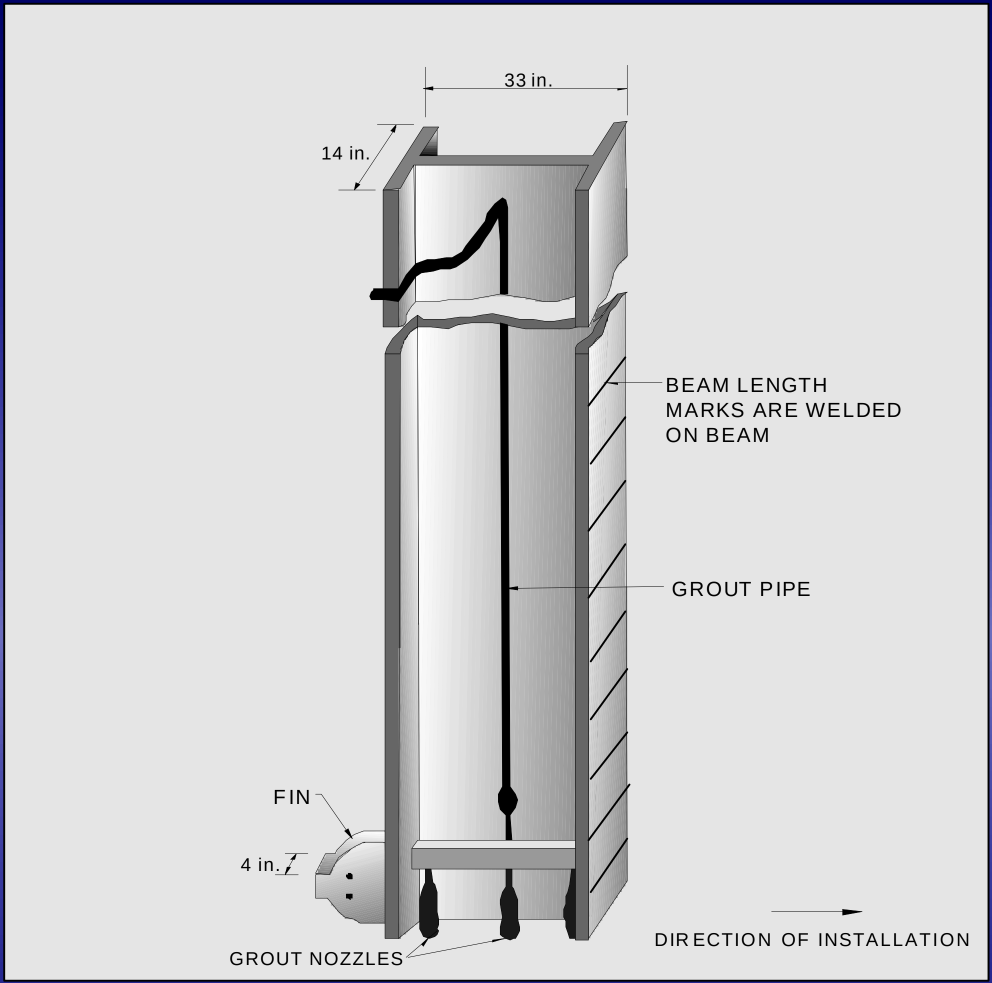
GEOMEMBRANE CUT-OFF WALL

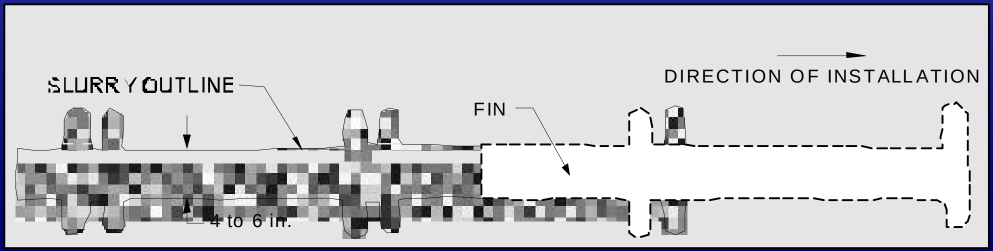
KEY ATTRIBUTES

- ✓ Moderate cost
- ✓ Essentially impermeable
- ✓ Same limitations as soil-bentonite wall
- ✓ Higher degree of containment than soil-bentonite wall
- ✓ Watertight joints require skillful construction

SUBSURFACE BARRIERS

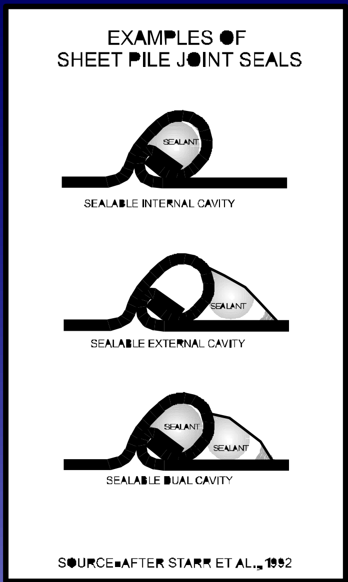
VIBRATING BEAM WALL

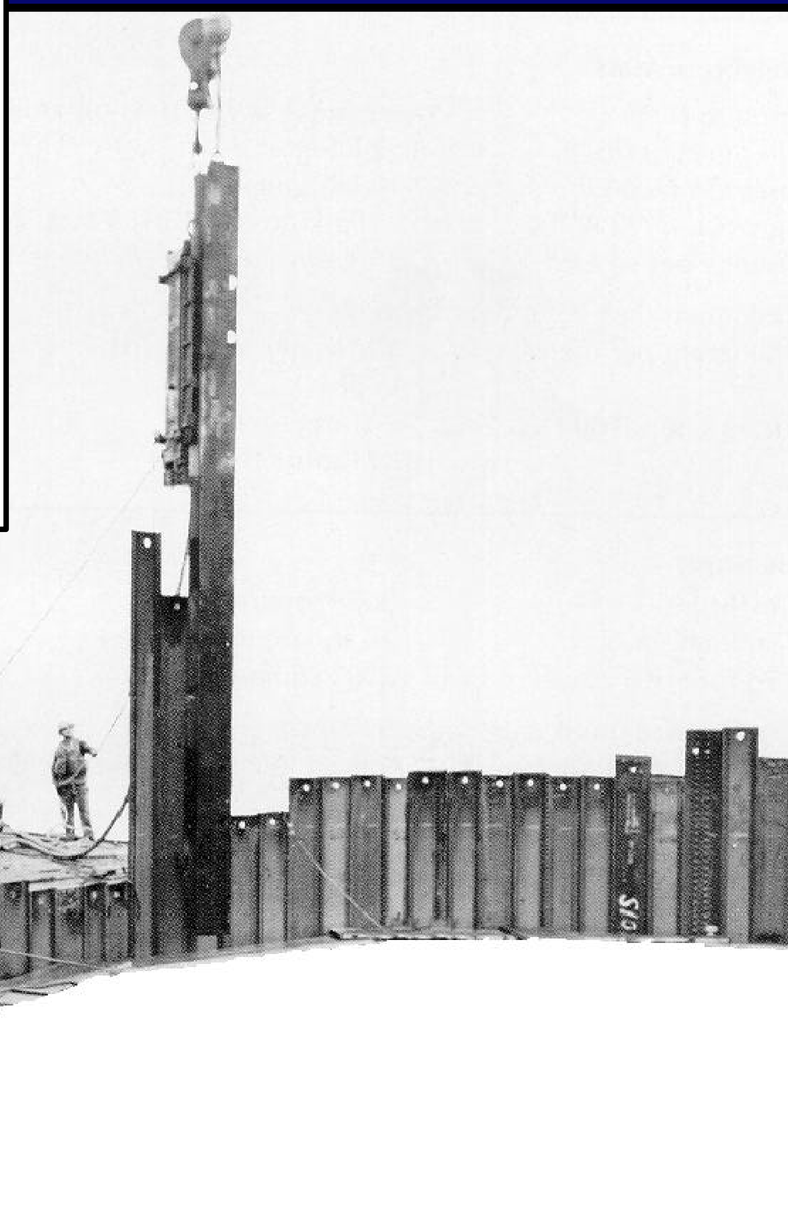




KEY ATTRIBUTES

- Low to moderate cost and permeability
- Cannot penetrate stiff soils and bedrock
- Produces thin wall with potential for defects
- Does not require soil excavation, little right-of-way needed
- Available from only a few specialty contractors





SUBSURFACE BARRIERS

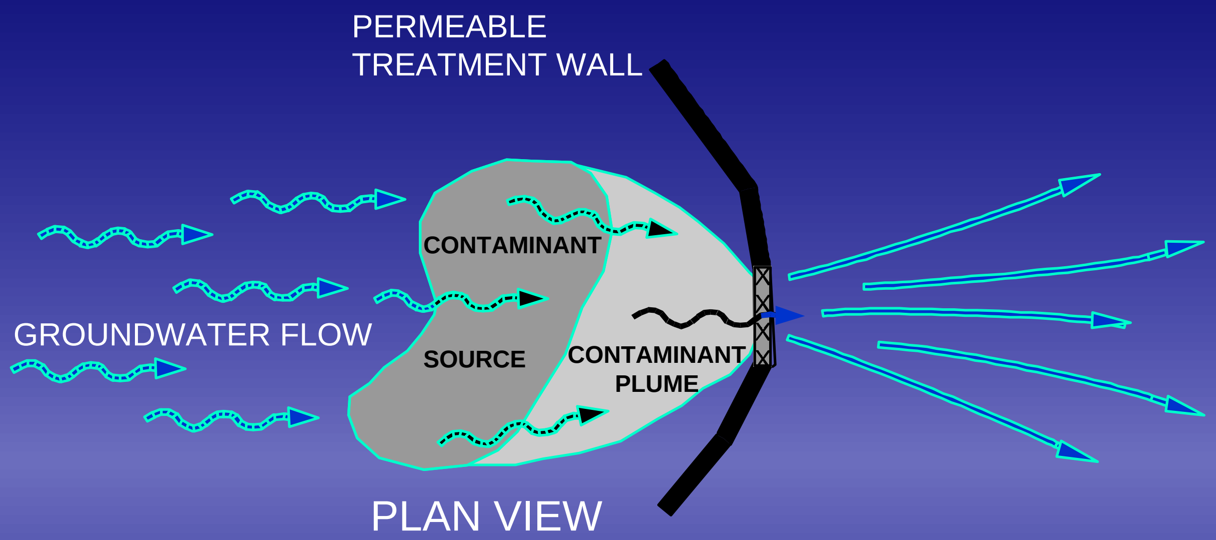
SHEET PILE WALL

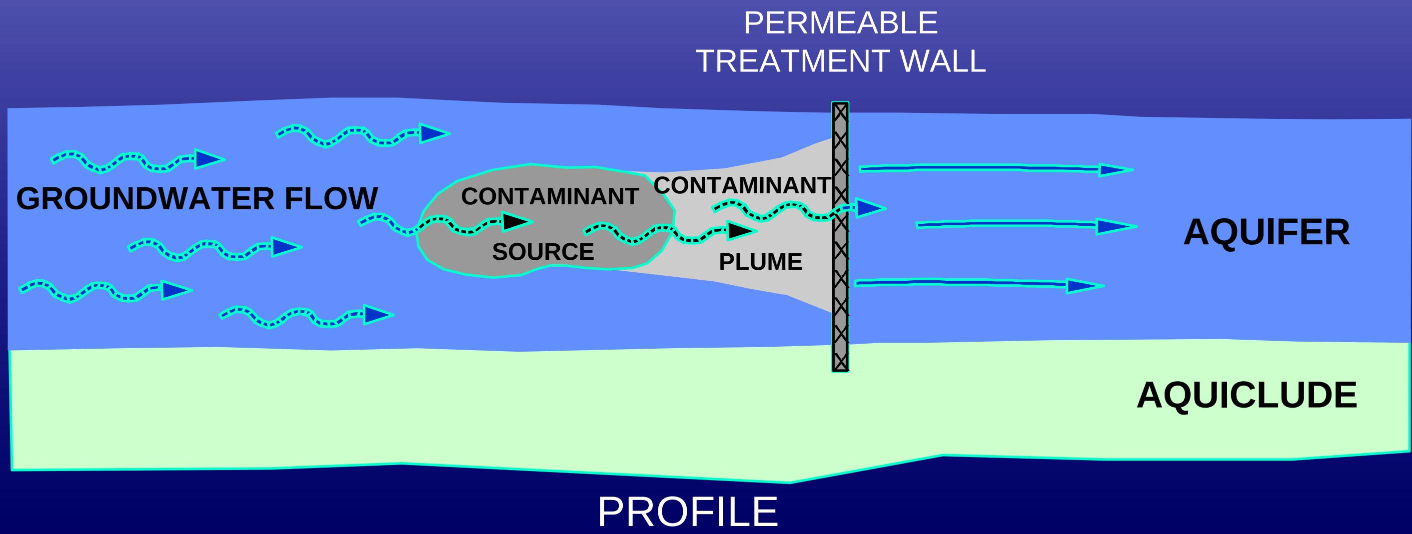
KEY ATTRIBUTES

- ✓ Moderate to high cost
- ✓ Very low permeability with special seals
- ✓ Can withstand hard driving
- ✓ Does not require soil excavation, little right-of-way needed
- ✓ Can improve foundation structural capacity
- ✓ Requires specialty contractors

SUBSURFACE BARRIERS

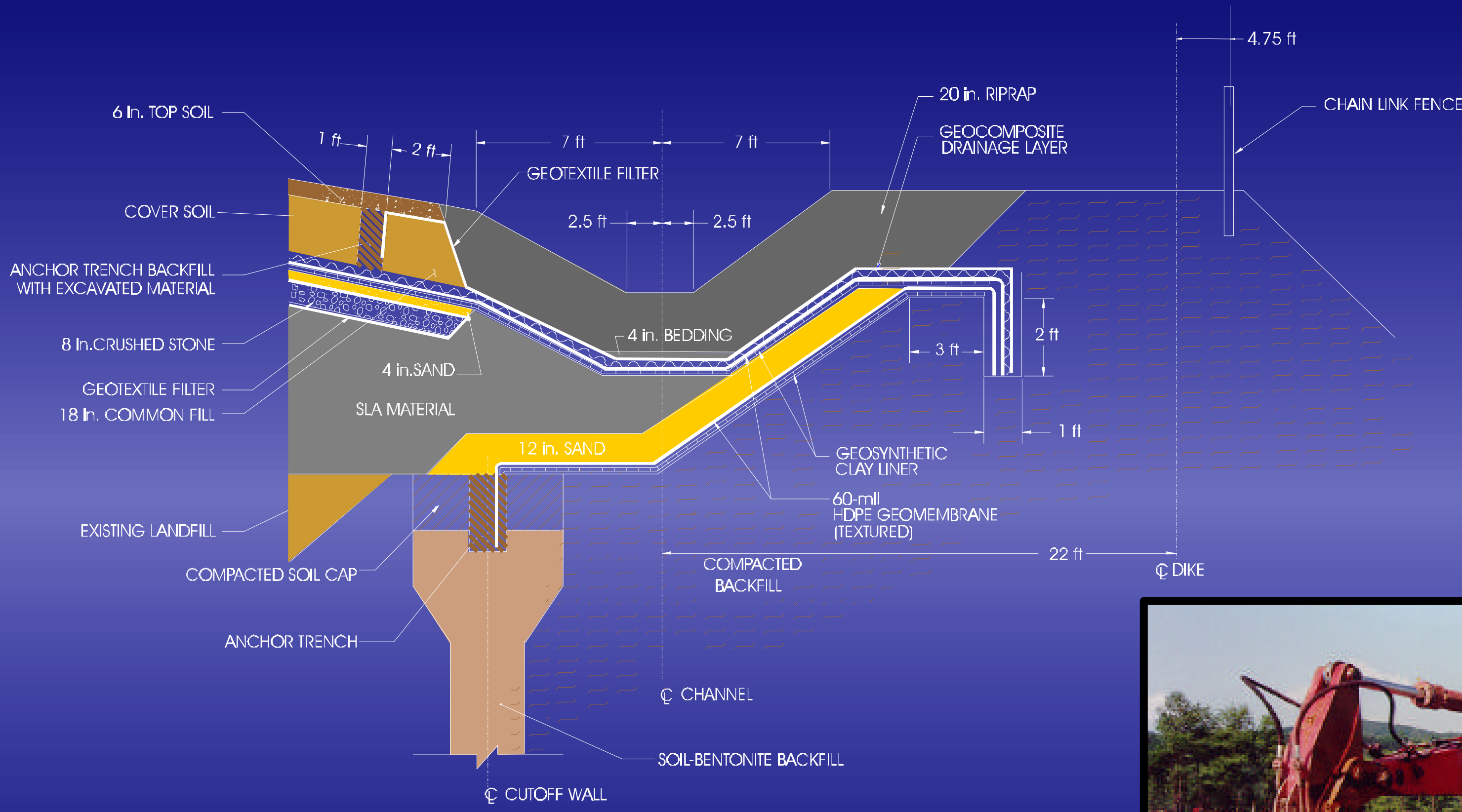
PERMEABLE TREATMENT WALL





SUBSURFACE BARRIERS

NEW YORK SUPERFUND SITE



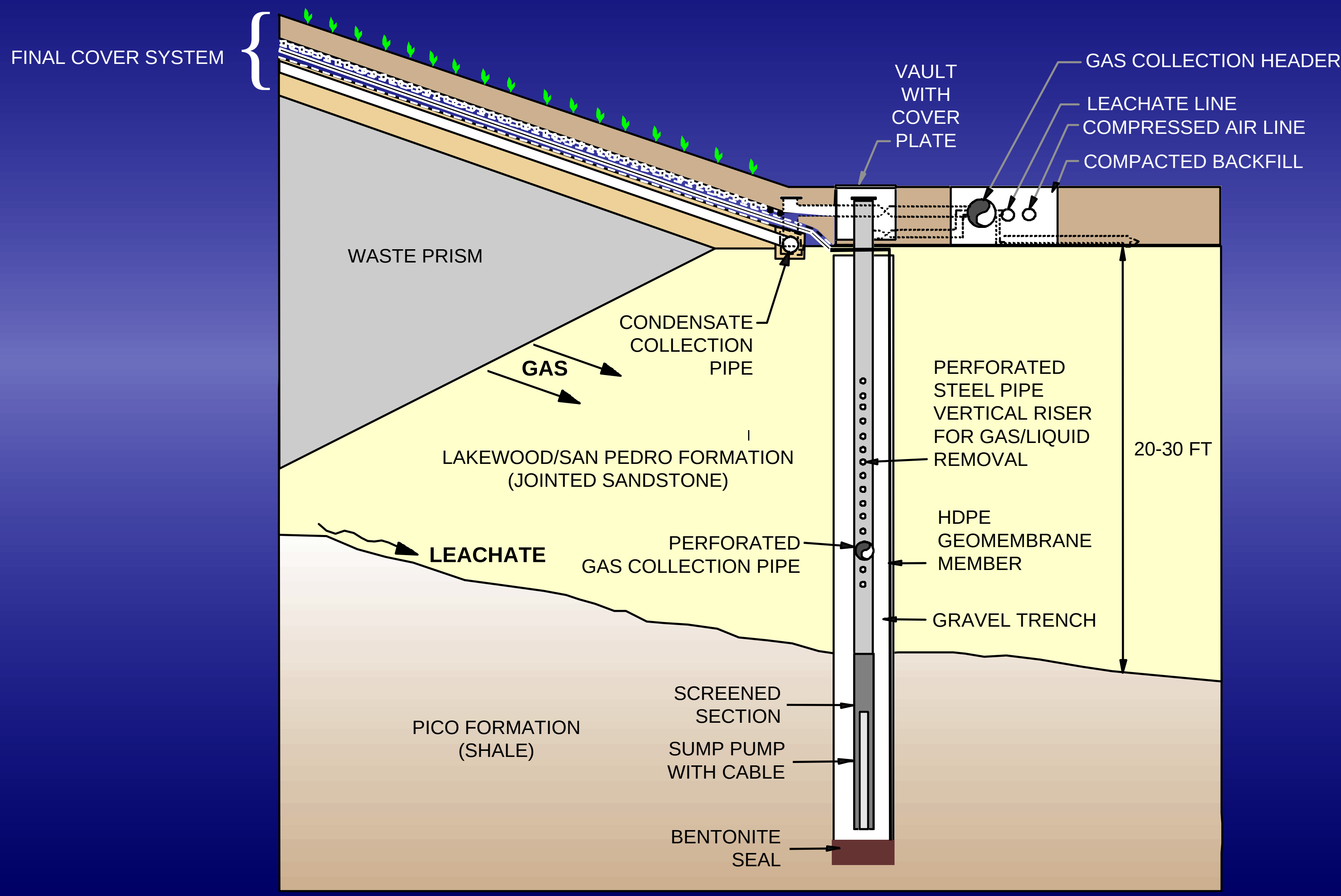
SLURRY TRENCH EXCAVATION

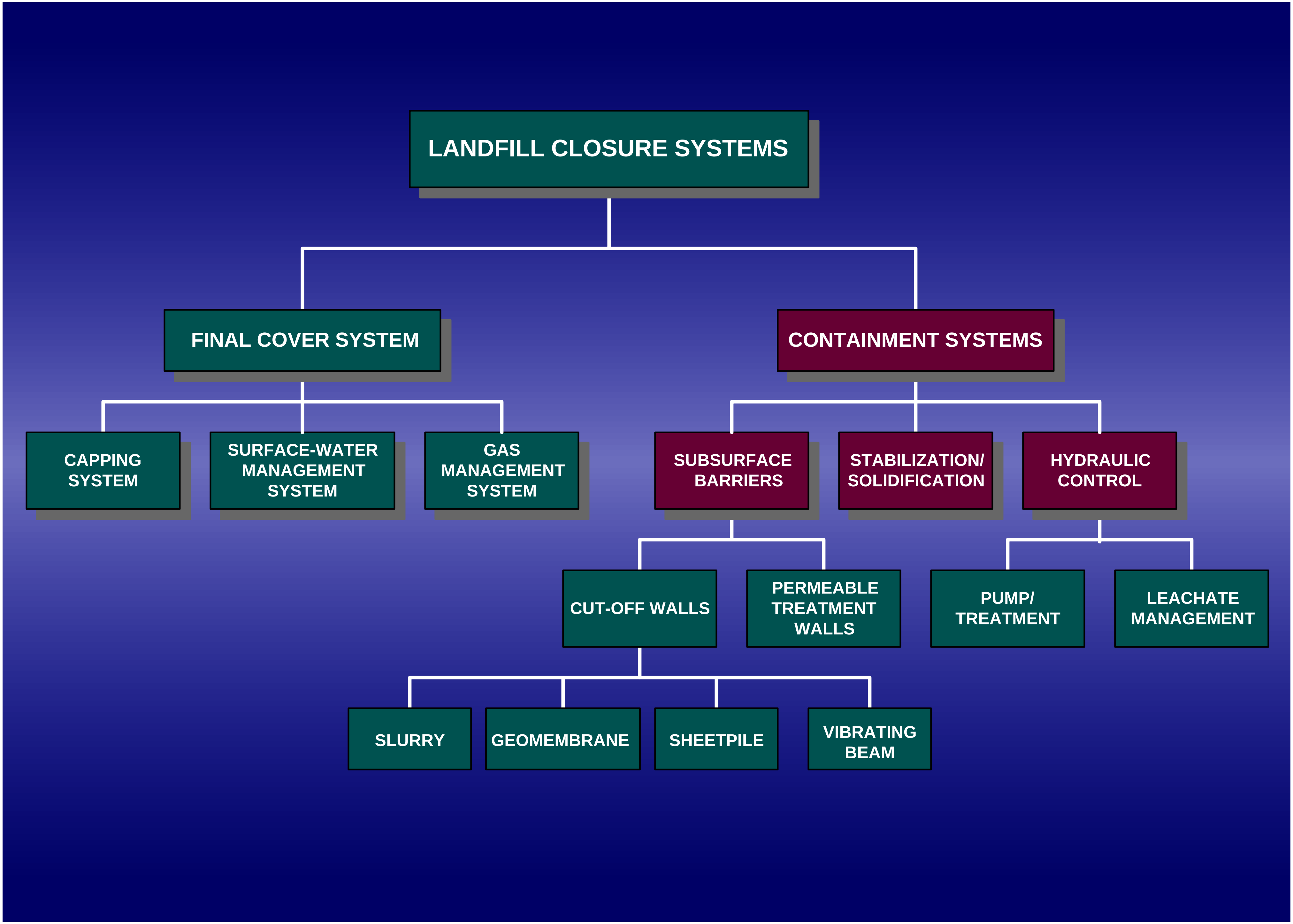
SUBSURFACE BARRIERS

NEW YORK SUPERFUND SITE

SUBSURFACE BARRIERS

CALIFORNIA SUPERFUND SITE




LANDFILL CLOSURE SYSTEMS
FINAL COVER SYSTEM
CONTAINMENT SYSTEMS
CAPPING SYSTEM
SURFACE-WATER MANAGEMENT SYSTEM
GAS MANAGEMENT SYSTEM
SUBSURFACE BARRIERS
STABILIZATION/ SOLIDIFICATION
HYDRAULIC CONTROL
CUT-OFF WALLS
PERMEABLE TREATMENT WALLS
PUMP/ TREATMENT
LEACHATE MANAGEMENT
SLURRY
GEOMEMBRANE
SHEETPILE
VIBRATING BEAM

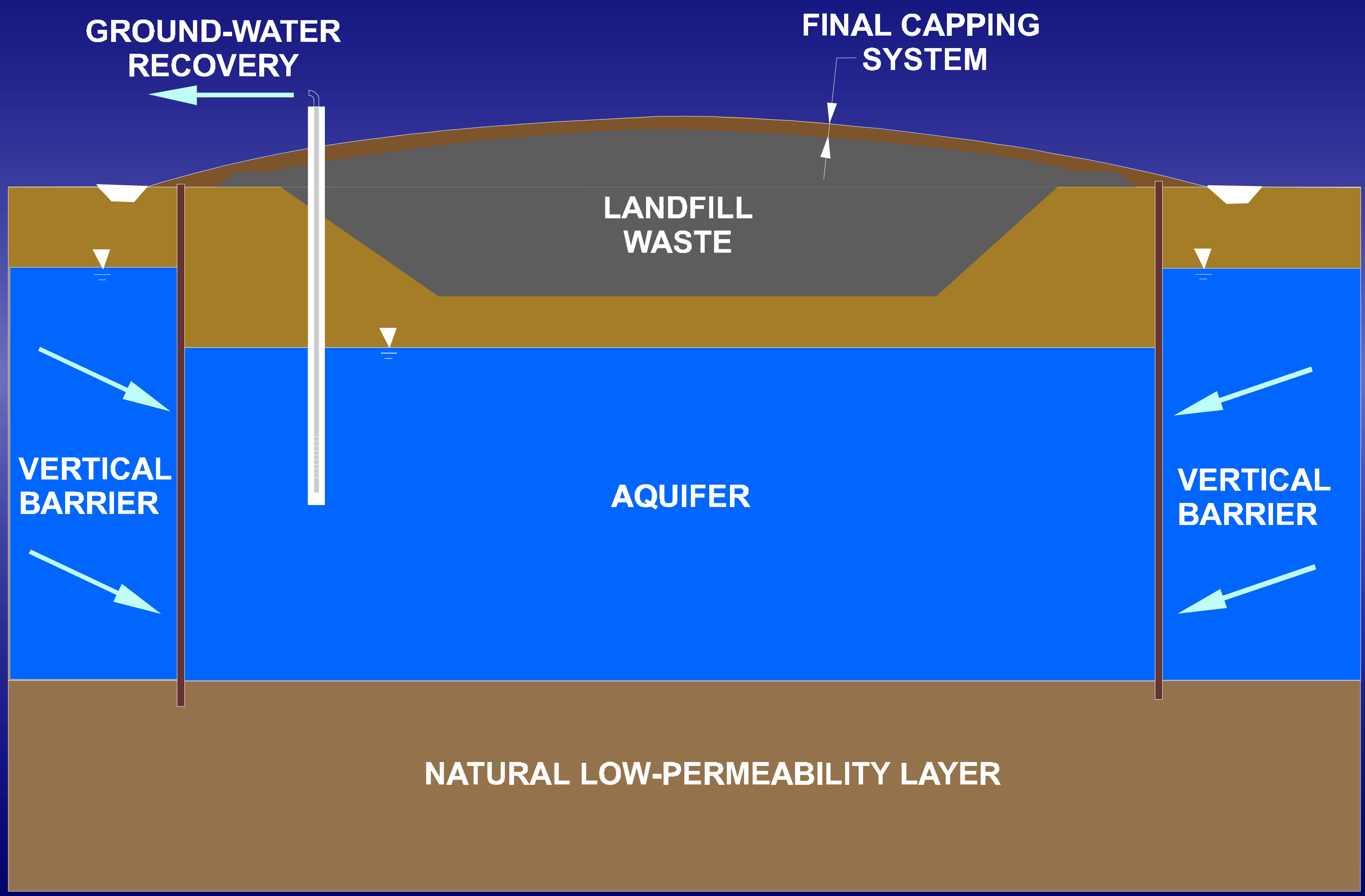
CLOSURE SYSTEM COMPONENTS

SOLIDIFICATION/STABILIZATION

- Mixing, blending, or injection of physical/chemical additives to:
  - Provide stable foundation for final cover system construction
  - Reduce contaminant mobility or solubility
  - Improve the handling or hydraulic characteristics of a waste
- Solidification refers to the process in which materials are added to a waste to produce a solid
- Stabilization refers to converting a waste to a more chemically stable form

CLOSURE SYSTEM COMPONENTS

HYDRAULIC CONTROL



DESIGN PROCESS

DESIGN PROCESS

- Pre-Design Studies
- Conceptual Design
  - CERCLA feasibility study (FS)
  - CERCLA engineering evaluation/cost analysis (EE/CA)
  - RCRA corrective measure study (CMS)
  - State Requirements
- Detailed Design
  - Preliminary (30%) Design
  - Pre-Final (90%) Design
  - Final (100%) Design
- Certified-for-Construction (CFC) Documents
  - Drawings and specifications
  - Work plans and contract documents

PRE-DESIGN STUDY

POTENTIAL PRE-DESIGN INVESTIGATION ACTIVITIES

AT THE SITE...

- Hydrogeological subsurface investigation
- Groundwater sampling and chemical analysis
- Geotechnical subsurface investigation
- Soil borrow source studies
- Clay liner test pad program

PRE-DESIGN STUDY

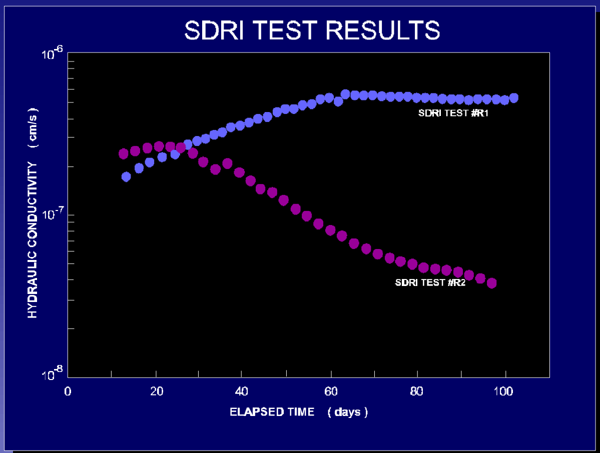
POTENTIAL PRE-DESIGN INVESTIGATION ACTIVITIES

IN THE LAB...

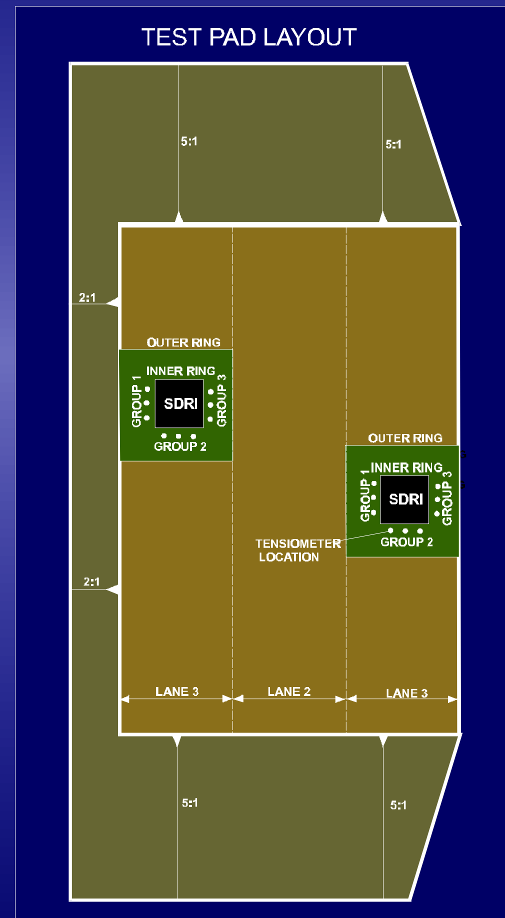
- Geotechnical laboratory testing
- Soil-geosynthetic interface testing program
- Waste property evaluation
- Barrier material testing
- Waste solidification/stabilization evaluation

PRE-DESIGN STUDY

SEALED DOUBLE-RING INFILTROMETER TESTING



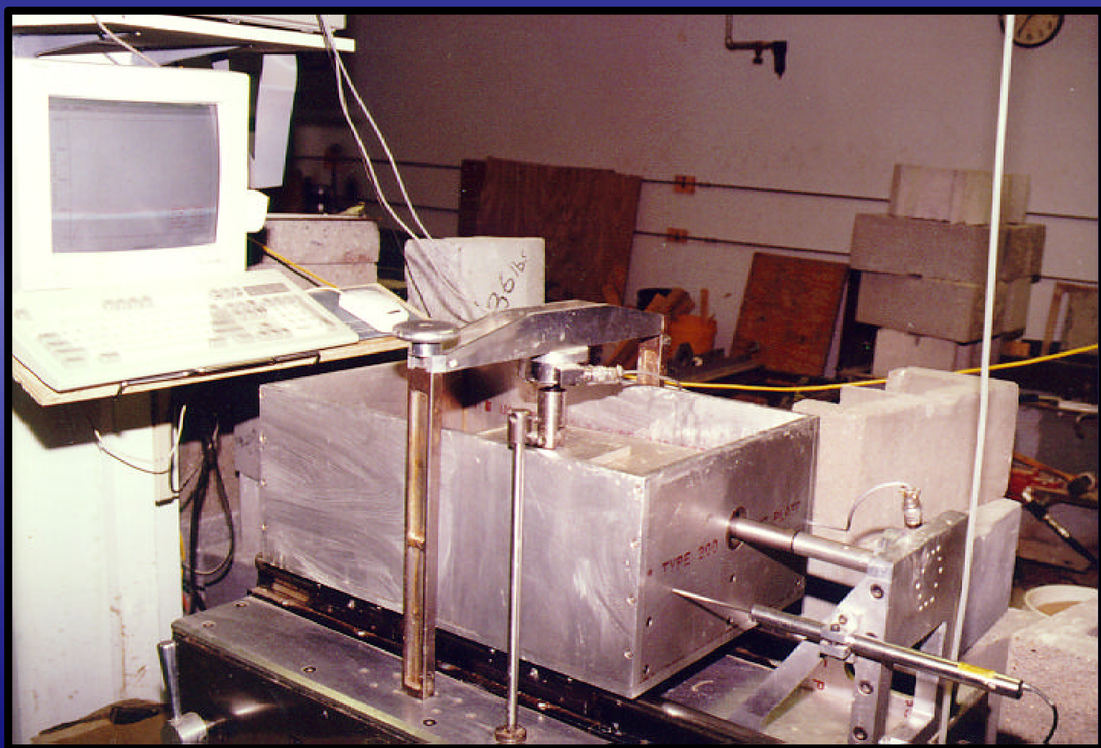
SEALED DOUBLE-RING INFILTRATION TESTING (SDRI)



PRE-DESIGN STUDY

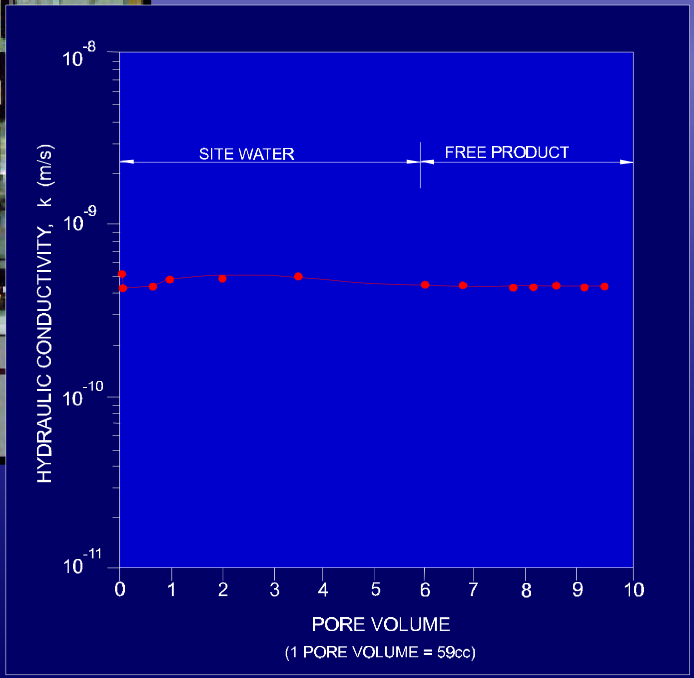
SOIL-GEOMEMBRANE INTERFACE TESTING

SAMPLE PREPARATION IN 12-IN. x 12-IN. SHEAR BOX



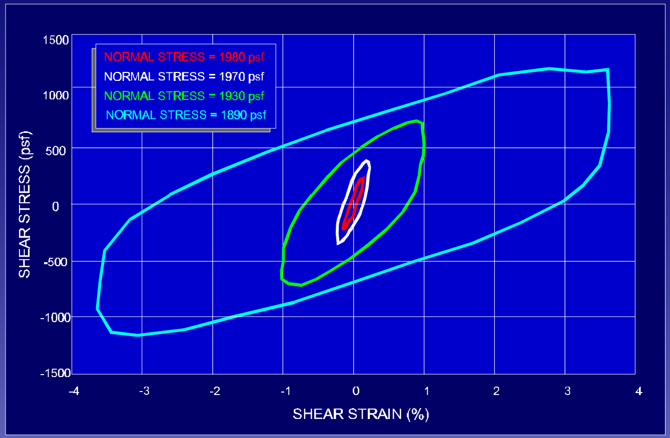
SHEAR TEST IN PROGRESS

PRE-DESIGN STUDY
SOIL-BENTONITE BACKFILL TESTING



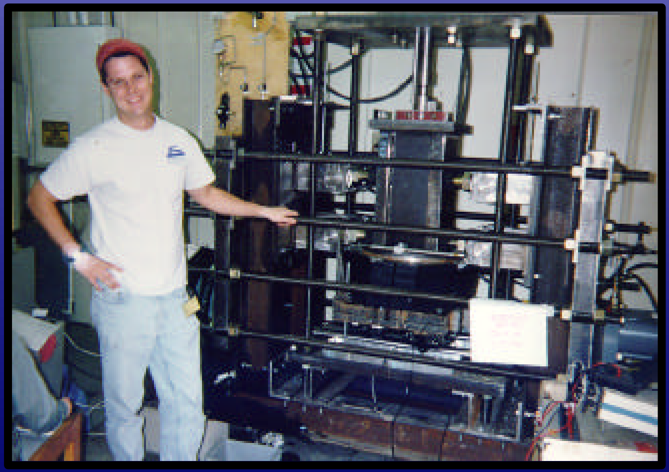
PRE-DESIGN STUDY

CYCLIC SIMPLE SHEAR TESTING OF WASTE MASS



CYCLIC SIMPLE SHEAR TEST RESULTS FOR WASTE SAMPLE

WASTE SAMPLING WITH LARGE-DIAMETER BUCKET AUGER



CYCLIC SIMPLE SHEAR DEVICE TO EVALUATE WASTE DYNAMIC PROPERTIES (18-IN. DIAMETER)

DESIGN PROCESS

DETAILED DESIGN FOR FINAL COVER SYSTEMS

DESIGN PROCESS

DETAILED DESIGN

1. LAYOUT AND GRADING
2. STORMWATER MANAGEMENT SYSTEM DESIGN
3. GAS MANAGEMENT SYSTEM DESIGN
4. SELECT CAP COMPONENTS
5. SETTLEMENT EVALUATION
6. CAP SYSTEM INFILTRATION ANALYSIS
7. FOUNDATION STABILITY EVALUATION
8. DRAINAGE LAYER DESIGN
9. CAP SLOPE STABILITY EVALUATION
10. EROSION CONTROL

DETAILED DESIGN

❶ LAYOUT AND GRADING

- Establish lateral limits of landfill
- Develop grading plan to minimize cut/fill requirements for waste and soil
- Establish benches to manage stormwater runoff and provide access
- Provide cover system access road as appropriate
- Develop final grading consistent with existing slopes, stormwater management, and slope stability

DETAILED DESIGN

❷ STORMWATER MANAGEMENT SYSTEM DESIGN

- Select design storm events (typical 25-yr. 24-hr.)
- Perform runoff and runon routing analysis
- Design letdown structures to handle runoff
- Size perimeter channels, ditches, culverts, and outlet structures
- Size stormwater detention basin (if needed)

DETAILED DESIGN

❸ GAS MANAGEMENT SYSTEM DESIGN

- Prevent gas migration by convection and diffusion
- Passive systems intercept gas and channel to collection point or vent
- Active systems create pressure gradient
- Rule of thumb: one vent per acre of cap

DETAILED DESIGN

❹ SELECT CAP COMPONENTS

- Identify CERCLA ARARs, RCRA requirements, or other (e.g., state program) design requirements
- Evaluate required performance levels (e.g., percent reduction in infiltration)
- Evaluate requirements for slope stability
- Evaluate requirements for freeze-thaw protection of components
- Assess material availability
- Choose components

DETAILED DESIGN

POTENTIAL MATERIALS

Surface layer
- Top soil
- Geosynthetic erosion control layer
- Cobbles
- Paving material
- Others

Protection layer
- Soil
- Cobbles
- Others

Drainage layer
- Sand
- Gravel
- Geonet
- Others

Barrier layer
- Compacted clay
- Geomembrane
- Geosynthetic clay liner (GCL)
- Geomembrane/compacted clay composite
- Geomembrane/GCL composite
- GCL/compacted clay composite
- Others

Gas Collection layer
- Sand
- Gravel
- Geotextile
- Geonet
- Others

Foundation layer
- Soil
- Select waste
- Others

DETAILED DESIGN

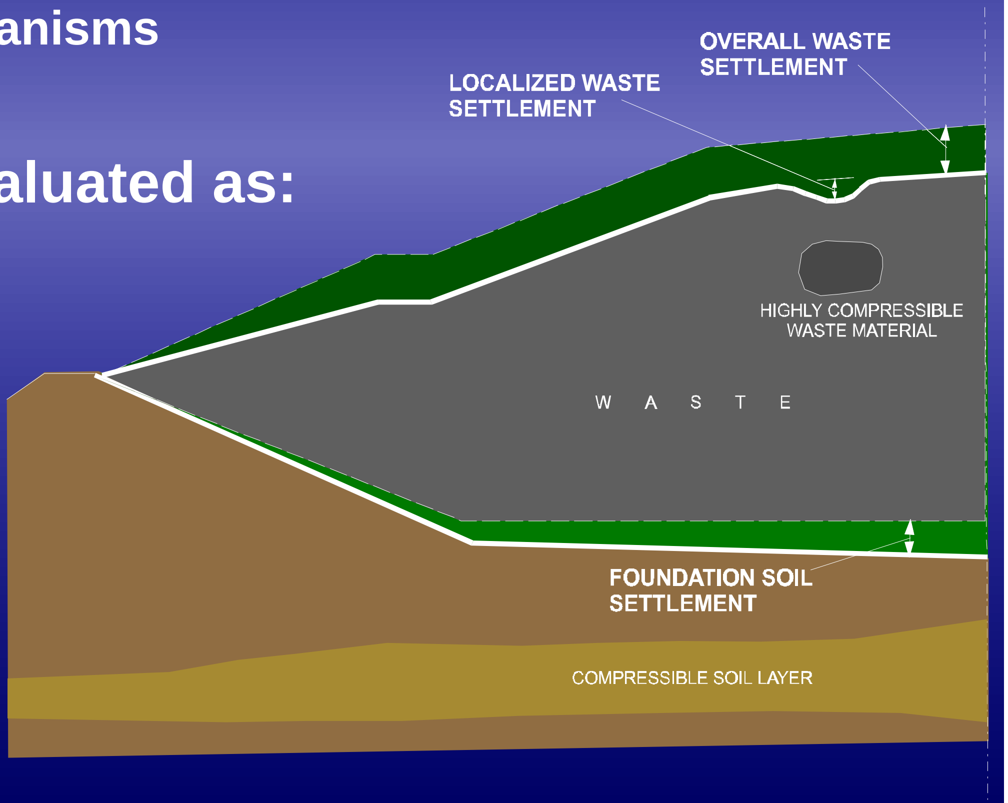
❺ SETTLEMENT EVALUATION

Sources are:

- Settlement of foundation soils
- Settlement due to overall waste mass compressibility
- Settlement due to localized mechanisms

Overall waste mass compression evaluated as:

- Primary (load dependent)
- Secondary (time dependent)



DETAILED DESIGN

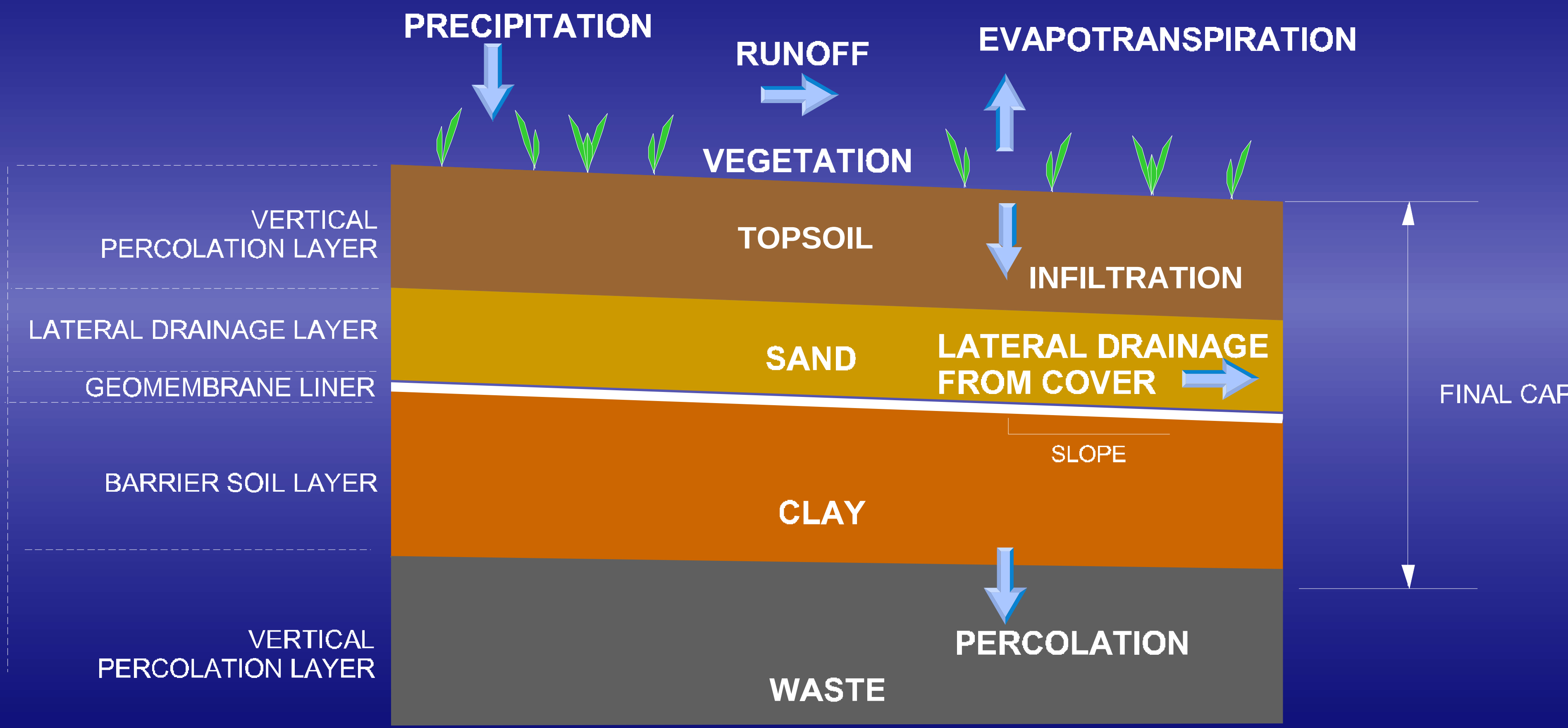
❻ CAP SYSTEM INFILTRATION ANALYSIS

- Calculate water balance of the final cover system and waste source using USEPA HELP model

- Estimate geomembrane leakage

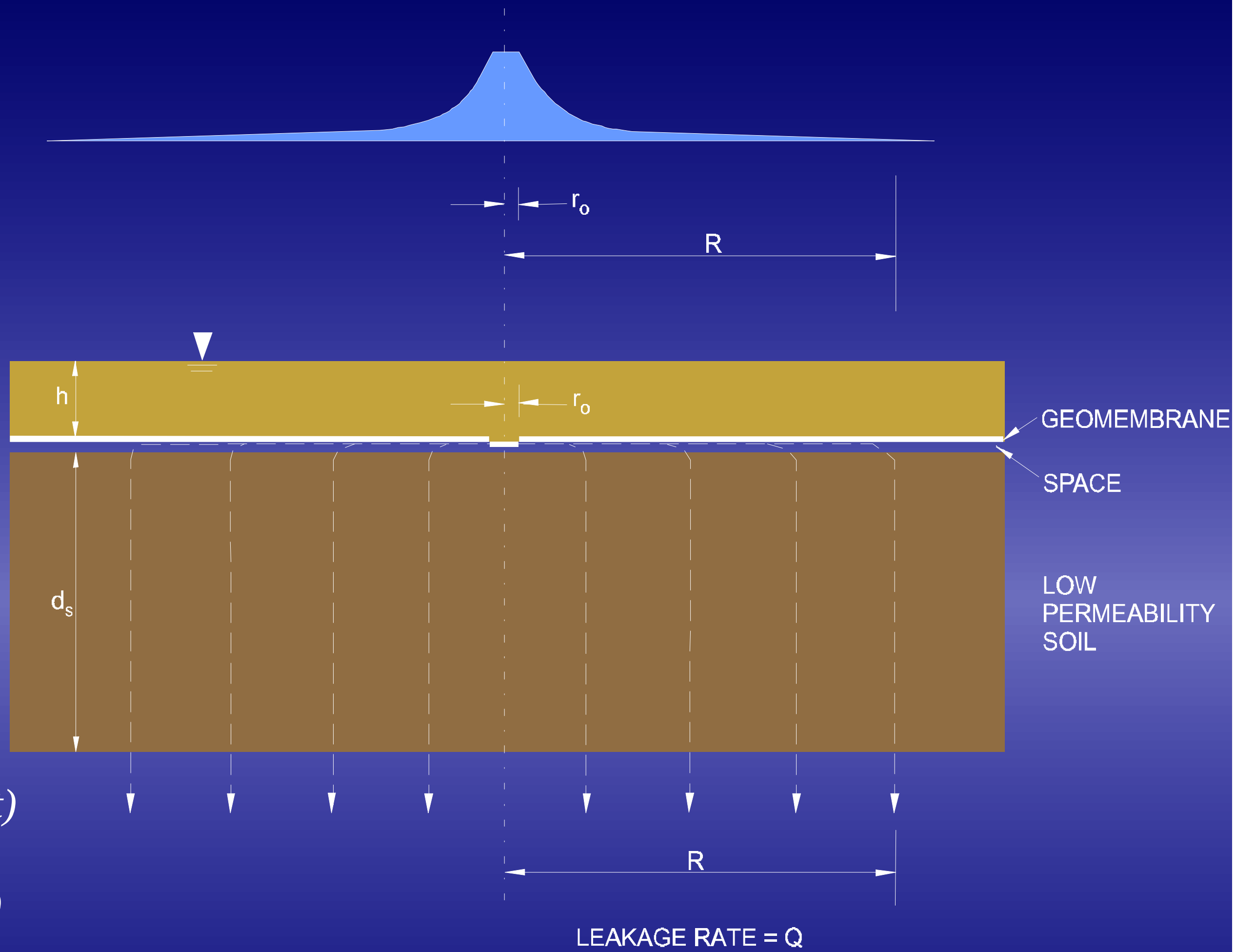
DETAILED DESIGN

LANDFILL WATER BALANCE



DETAILED DESIGN

GEOMEMBRANE LEAKAGE



$Q = 0.21\ a^{0.1}\ h^{0.9}\ k^{0.74}$ *(for good contact)*

$Q = 1.15\ a^{0.1}\ h^{0.9}\ k^{0.74}$ *(for poor contact)*

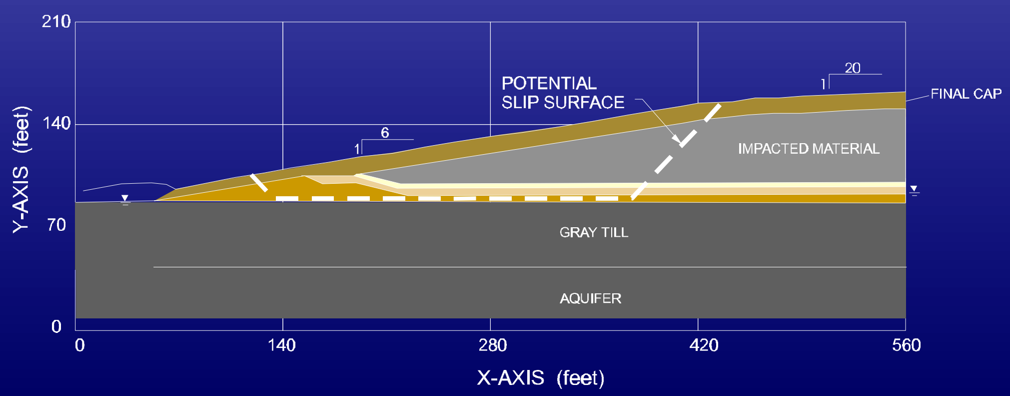
where: Q = infiltration rate through cap (m^3/s)
a = geomembrane hole area (m^2)
h = hydraulic head on cap (m)
k = hydraulic conductivity of cap soil (m/s)

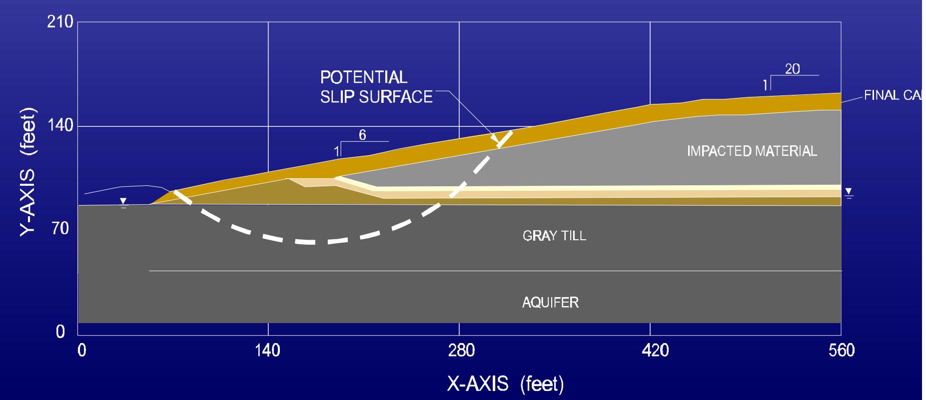
From Giroud and Bonaparte, 198

DETAILED DESIGN

❼ FOUNDATION STABILITY EVALUATION

- Perform subsurface investigation as necessary to establish foundation shear strength
- Calculate foundation stability factor of safety using classical methods of geotechnical engineering
- Address special problems of building on sludge, in marsh, etc., as necessary
- Check seismic foundation stability if required





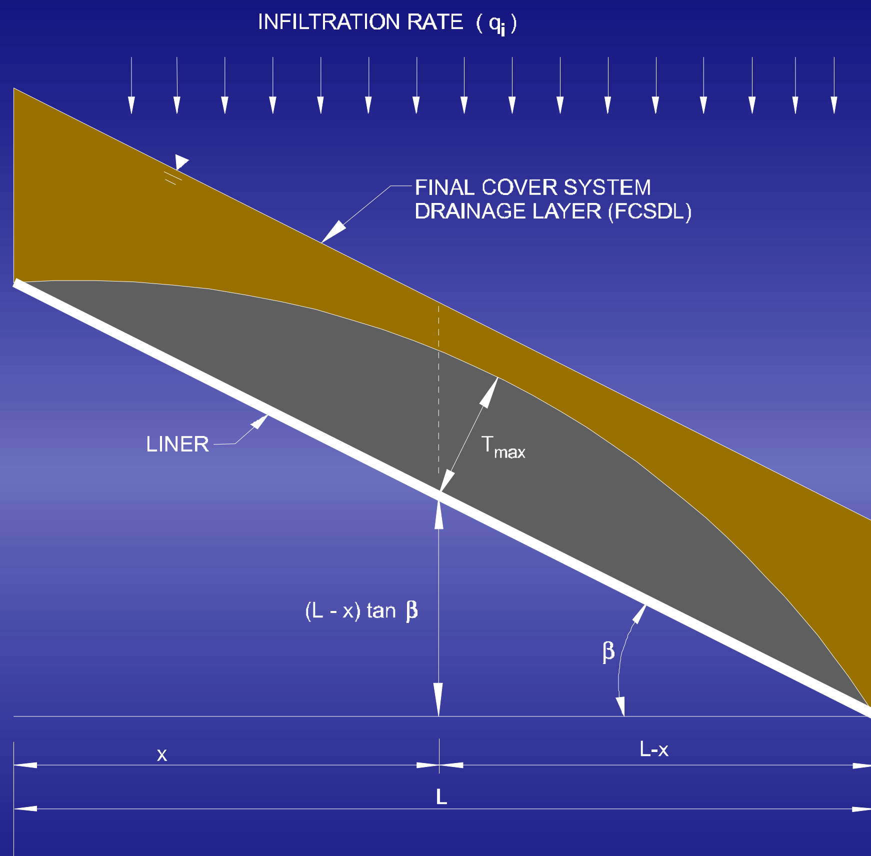
DETAILED DESIGN

❽ DRAINAGE LAYER DESIGN

$$\frac{T_{max}}{L} = \left[1 - 0.12\exp\left[-\left[\log(8\lambda/5)^{5/8}\right]^2\right]\right]\frac{\sqrt{1+4\lambda}-1}{2}\frac{(\tan\beta)}{(\cos\beta)}$$

$$\lambda = \frac{q_i/k}{\tan^2\beta}$$

$$T_{ave} = \frac{q_i\,L}{2\,k\sin\beta}$$



FROM GIROUD AND HOULIHAN, 1995

T_{max} = maximum liquid thickness (m)
T_{ave} = average liquid thickness (m)
L = slope length (m)
k = hydraulic conductivity of LCS (m/s)
β = slope angle (degrees)
q_i = infiltration rate (m/s)

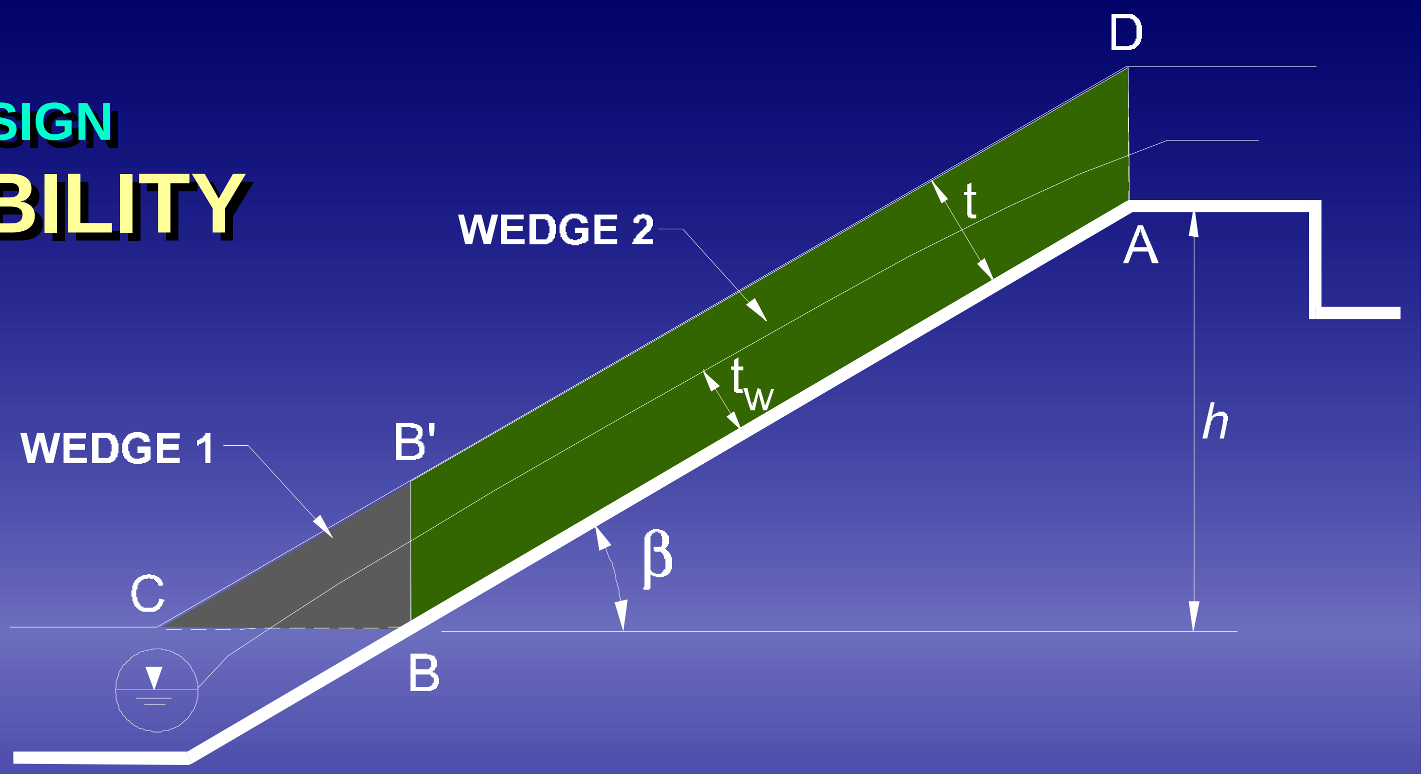
DETAILED DESIGN

❾ CAP SLOPE STABILITY EVALUATION

- Perform direct shear testing to evaluate soil-geosynthetic interface strengths
- Calculate slope stability factors of safety considering:
  - critical interface
  - pore water pressure
  - toe buttressing
  - geosynthetic reinforcement
  - soil strength parameters
- Check seismic slope stability as required

DETAILED DESIGN

SLOPE STABILITY



Above geomembrane:

$$FS_A = \frac{\gamma_b}{\gamma_{sat}} \frac{\tan\delta_A}{\tan\beta} + \frac{a_A}{\gamma_{sat}\, t \sin\beta} + \frac{\gamma_b}{\gamma_{sat}} \frac{t}{h} \frac{\sin\phi}{2\sin\beta\cos\beta\cos(\beta+\phi)} + \frac{c}{\gamma_{sat}\, h} \frac{\cos\phi}{\sin\beta\cos(\beta+\phi)} + \frac{T}{\gamma_{sat}\, t\, h}$$

Below geomembrane:

$$FS_B = \frac{\tan\delta_B}{\tan\beta} + \frac{a_B}{\gamma_{sat}\, t \sin\beta} + \frac{\gamma_b}{\gamma_{sat}} \frac{t}{h} \frac{\sin\phi}{2\sin\beta\cos\beta\cos(\beta+\phi)} + \frac{c}{\gamma_{sat}\, h} \frac{\cos\phi}{\sin\beta\cos(\beta+\phi)} + \frac{T}{\gamma_{sat}\, t\, h}$$

FROM GIROUD AND HOULIHAN, 1995

DETAILED DESIGN

⑩ EROSION CONTROL

- Select location of construction-phase silt fences and straw bales
- Specify erosion-control matting for erodible exposed slopes
- Select topsoil, seed, and fertilizer mixes for final revegetation
- Specify riprap or other protection for culvert and ditch entrances and exits as necessary
- Universal soil loss equation: A = R x K x LS x VM

  A = rate of soil loss

  R = rainfall energy factor

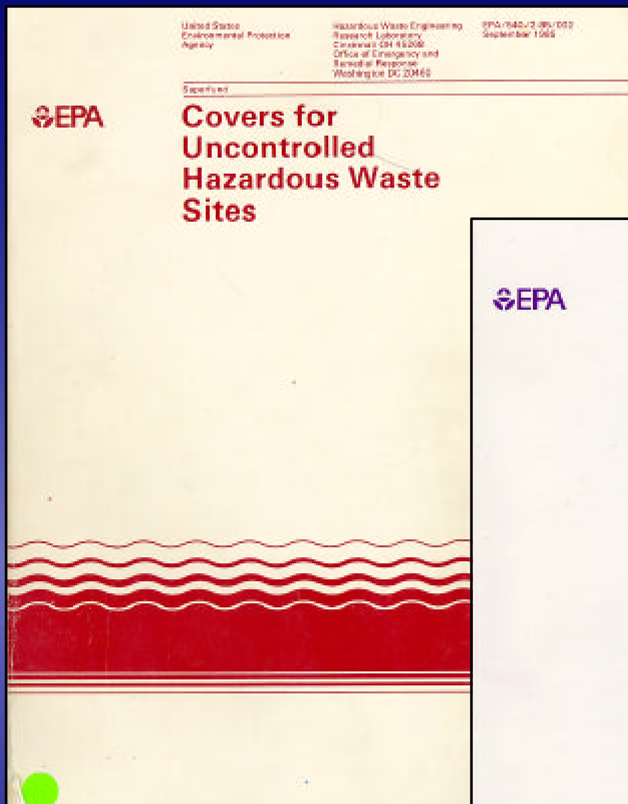
  K = length and slope factor

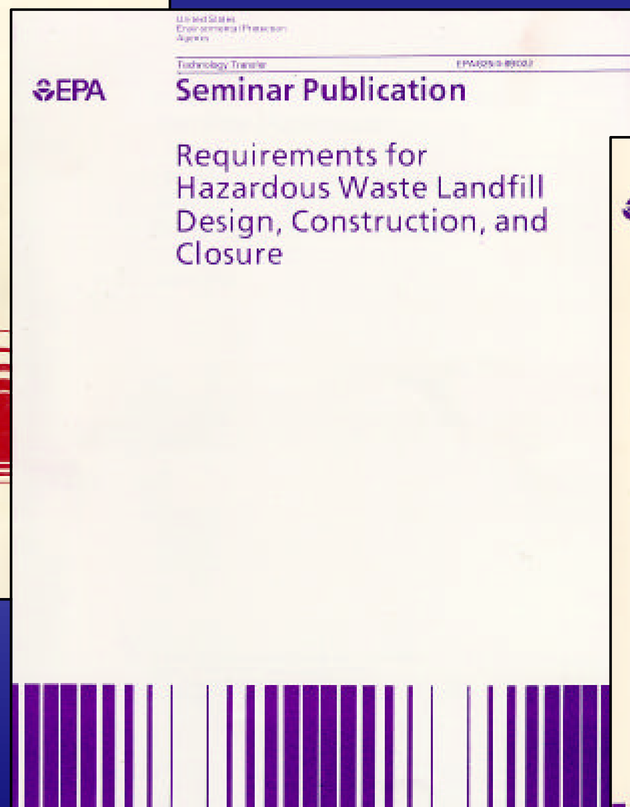
  LS = soil erodibility factor

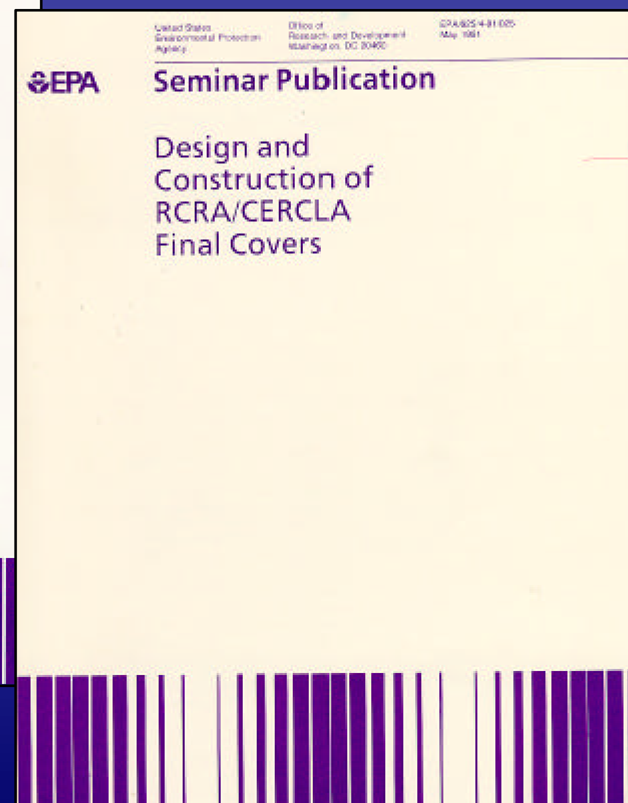
  VM = vegetative measures factor

DESIGN PROCESS

GUIDANCE PUBLICATIONS







FOR MORE INFORMATION:

United States Environmental Protection Agency

Office of Solid Waste and Emergency Response

Directive No. 9355.0-49FS
EPA 540-F-93-035
PB 93-963339
September 1993

EPA

Presumptive Remedy for CERCLA Municipal Landfill Sites

Office of Emergency and Remedial Response
Hazardous Site Control Division 5203G

Quick Reference Fact Sheet

Since Superfund's inception in 1980, the remedial and removal programs have found that certain categories of sites have similar characteristics, such as types of contaminants present, types of disposal practices, or how environmental media are affected. Based on information acquired from evaluating and cleaning up these sites, the Superfund program is undertaking an initiative to develop presumptive remedies to accelerate future cleanups at these types of sites. The presumptive remedy approach is one tool of acceleration within the **Superfund Accelerated Cleanup Model (SACM).**

Presumptive remedies are preferred technologies for common categories of sites, based on historical patterns of remedy selection and EPA's scientific and engineering evaluation of performance data on technology implementation. The objective of the presumptive remedies initiative is to use the program's past experience to streamline site investigation and speed up selection of cleanup actions. Over time presumptive remedies are expected to ensure consistency in remedy selection and reduce the cost and time required to clean up similar types of sites. Presumptive remedies are expected to be used at all appropriate sites except under unusual site-specific circumstances.

This directive establishes **containment** as the presumptive remedy for CERCLA municipal landfills. The framework for the presumptive remedy for these sites is presented in a streamlining manual entitled *Conducting Remedial Investigations/Feasibility Studies for CERCLA Municipal Landfill Sites*, February 1991 (OSWER Directive 9355. 3-11). This directive highlights and emphasizes the importance of certain streamlining principles related to the scoping (planning) stages of the remedial investigation/feasibility study (RI/FS) that were identified in the manual. The directive also provides clarification of and additional guidance in the following areas: (1) the level of detail appropriate for risk assessment of source areas at municipal landfills and (2) the characterization of hot spots.

BACKGROUND

Superfund has conducted pilot projects at four municipal landfill sites[1] on the National Priorities List (NPL) to evaluate the effectiveness of the manual *Conducting Remedial Investigations/Feasibility Studies for CERCLA Municipal Landfill Sites* (hereafter referred to as "the manual") as a streamlining tool and as the framework for the municipal landfill presumptive remedy. Consistent with the National Oil and Hazardous Substances Pollution Contingency Plan (or NCP), EPA's expectation was that containment technologies generally would be appropriate for municipal landfill waste because the volume and heterogeneity of the waste generally make treatment impracticable. The results of the pilots support this expectation and demonstrate that the manual is an effective tool for streamlining the RI/FS process for municipal landfills.

Since the manual's development, the expectation to contain wastes at municipal landfills has evolved into a presumptive remedy for these sites.[2] Implementation of the streamlining principles outlined in the manual at the four pilot sites helped to highlight issues requiring further clarification, such as the degree to which risk assessments can be streamlined for source areas and the characterization and remediation of hot spots. The pilots also demonstrated the value of focusing streamlining efforts at the scoping stage, recognizing that the biggest savings in time and money can be realized if streamlining is incorporated at the beginning of the RI/FS process. Accordingly, this directive addresses those issues identified during the pilots and highlights streamlining opportunities to be considered during the scoping component of the RI/FS.

[1] Municipal landfill sites typically contain a combination of principally municipal and to a lesser extent hazardous wastes.

[2] See EPA Publication 9203.1-021, SACM Bulletins, *Presumptive Remedies for Municipal Landfill Sites*, April 1992, Vol. 1, No. 1 and February 1993, Vol. 2, No.1, and SACM Bulletin *Presumptive Remedies*, August 1992, Vol.1, No. 3.

Finally, while the primary focus of the municipal landfill manual is on streamlining the RI/FS, Superfund's goal under SACM is to accelerate the entire clean-up process. Other guidance issued under the municipal landfill presumptive remedy initiative identifies design data that may be collected during the RI/FS to streamline the ...all response process for these sites (see Publication ... 9355.3-18FS, *Presumptive Remedies: CERCLA ...dfill Caps Data Collection Guide*, to be published in ...ober 1993).

...NTAINMENT AS A PRESUMPTIVE ...EMEDY

...tion 300.430(a)(iii)(B) of the NCP contains the ...ectation that engineering controls, such as ...tainment, will be used for waste that poses a relatively ...long-term threat or where treatment is impracticable. ...e preamble to the NCP identifies municipal landfills ...a type of site where treatment of the waste may be ...practicable because of the size and heterogeneity of ...contents (55 FR 8704). Waste in CERCLA landfills ...ally is present in large volumes and is a heterogeneous ...xture of municipal waste frequently co-disposed ...h industrial and/or hazardous waste. Because ...atment usually is impracticable, EPA generally ...nsiders containment to be the appropriate response ...ion, or the "presumptive remedy," for the source ...eas of municipal landfill sites.

...e presumptive remedy for CERCLA municipal ...dfill sites relates primarily to containment of the ...dfill mass and collection and/or treatment of landfill ...s. In addition, measures to control landfill leachate, ...fected ground water at the perimeter of the landfill, ...d/or upgradient ground-water that is causing saturation ...f the landfill mass may be implemented as part of the ...esumptive remedy.

...he presumptive remedy does not address exposure ...athways outside the source area (landfill), nor does it ...clude the long-term ground-water response action. ...dditional RI/FS activities, including a risk assessment, ...ill need to be performed, as appropriate, to address ...ose exposure pathways outside the source area. It is ...xpected that RI/FS activities addressing exposure ...athways outside the source generally will be conducted ...oncurrently with the streamlined RI/FS for the landfill ...ource presumptive remedy. A response action for ...xposure pathways outside the source (if any) may be ...elected together with the presumptive remedy (thereby ...eveloping a comprehensive site response), or as an ...perable unit separate from the presumptive remedy.

...ighlight 1 identifies the components of the presumptive ...emedy. Response actions selected for individual sites ...ill include only those components that are necessary, ...ased on site-specific conditions.

Highlight 1: Components of the Presumptive Remedy: Source Containment

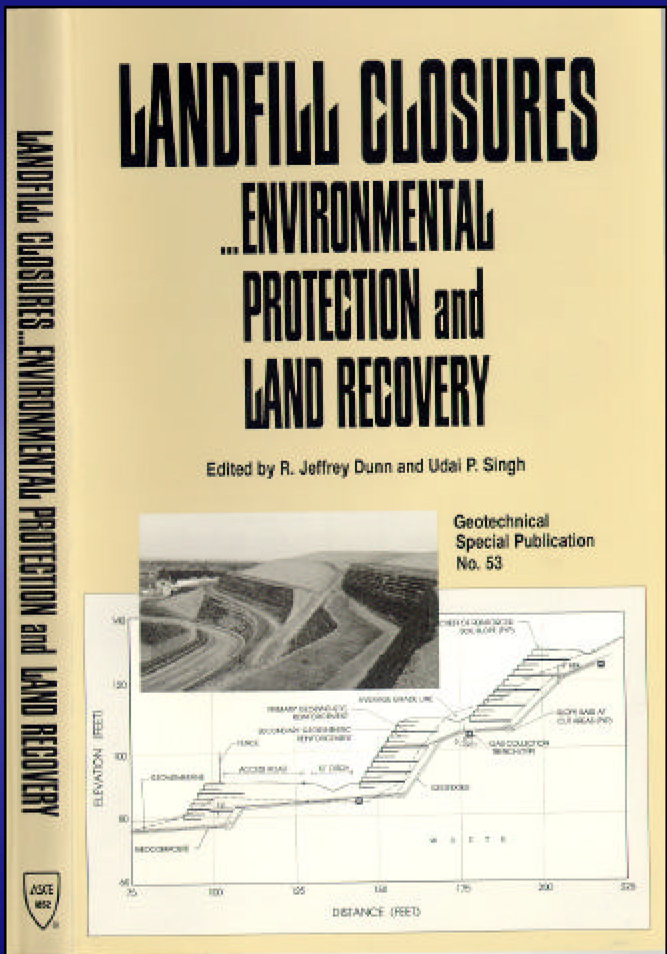
- Landfill cap;
- Source area ground-water control to contain plume;
- Leachate collection and treatment;
- Landfill gas collection and treatment; and/or
- Institutional controls to supplement engineering controls.

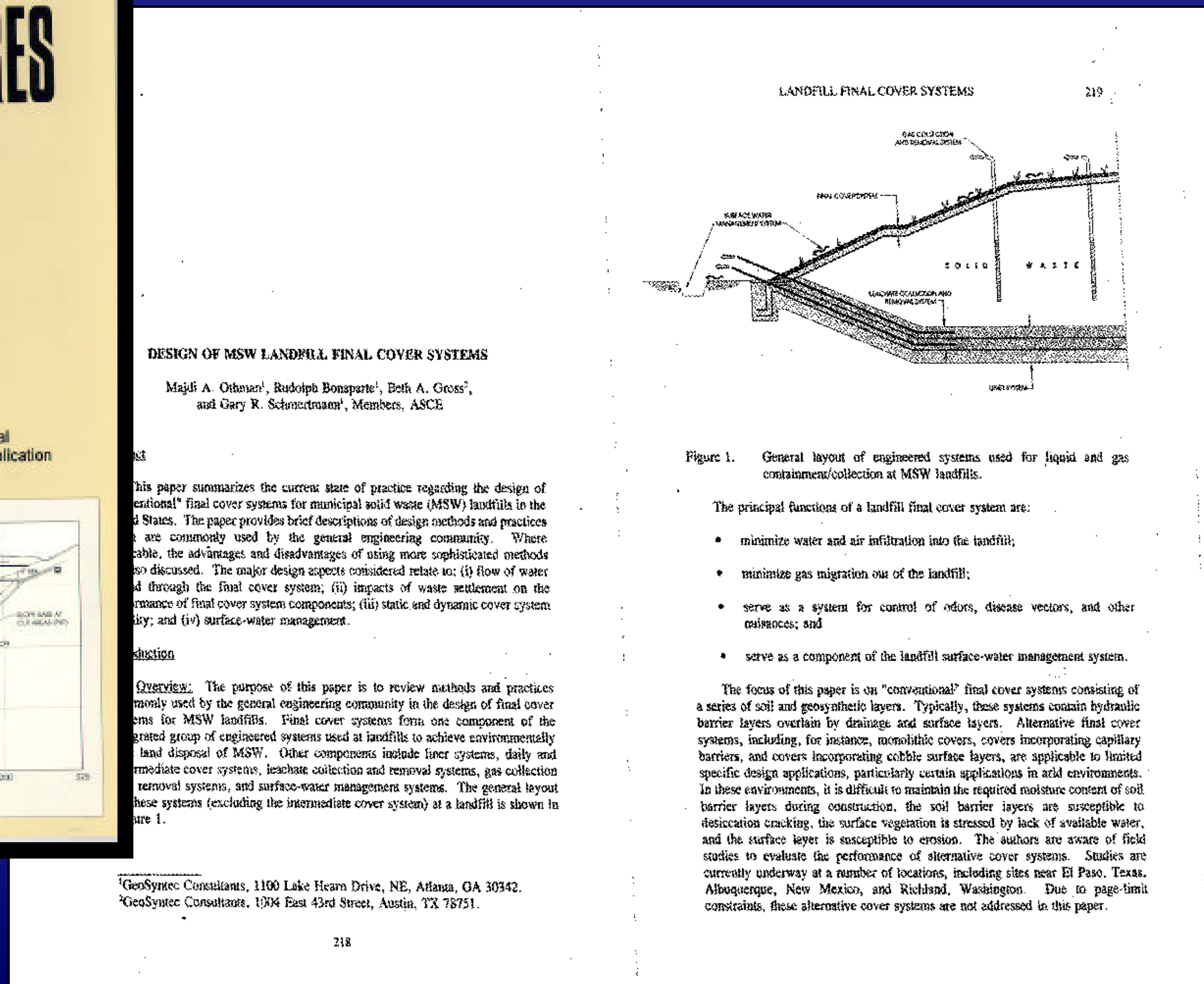
The EPA (or State) site manager will make the initial decision of whether a particular municipal landfill site is suitable for the presumptive remedy or whether a more comprehensive RI/FS is required. Generally, this determination will depend on whether the site is suitable for a streamlined risk evaluation, as described on page 4. The community, state, and potentially responsible parties (PRPs) should be notified that a presumptive remedy is being considered for the site before work on the RI/FS work plan is initiated. The notification may take the form of a fact sheet, a notice in a local newspaper, and/or a public meeting.

Use of the presumptive remedy eliminates the need for the initial identification and screening of alternatives during the feasibility study (FS). Section 300.430(e)(1) of the NCP states that, "... the lead agency shall include an alternatives screening step, when needed, (emphasis added) to select a reasonable number of alternatives for detailed analysis."

EPA conducted an analysis of potentially available technologies for municipal landfills and found that certain technologies are routinely and appropriately screened out on the basis of effectiveness, feasibility, or cost (NCP Section 300.430(e)(7)). (See Appendix A to this directive and "Feasibility Study Analysis for CERCLA Municipal Landfills," September 1993 available at EPA Headquarters and Regional Offices.) Based on this analysis, the universe of alternatives that will be analyzed in detail may be limited to the components of the containment remedy identified in Highlight 1, unless site-specific conditions dictate otherwise or alternatives are considered that were not addressed in the FS analysis. The FS analysis document, together with this directive, must be included in the administrative record for each municipal landfill presumptive remedy site to support elimination of the initial identification and screening of site-specific alternatives. Further detailed and comprehensive

FOR MORE INFORMATION:





DESIGN OF MSW LANDFILL FINAL COVER SYSTEMS

Majdi A. Othman[1], Rudolph Bonaparte[1], Beth A. Gross[2], and Gary R. Schmertmann[1], Members, ASCE

ast

his paper summarizes the current state of practice regarding the design of entional" final cover systems for municipal solid waste (MSW) landfills in the d States. The paper provides brief descriptions of design methods and practices are commonly used by the general engineering community. Where cable, the advantages and disadvantages of using more sophisticated methods so discussed. The major design aspects considered relate to: (i) flow of water d through the final cover system; (ii) impacts of waste settlement on the rmance of final cover system components; (iii) static and dynamic cover system ity; and (iv) surface-water management.

duction

Overview: The purpose of this paper is to review methods and practices monly used by the general engineering community in the design of final cover ems for MSW landfills. Final cover systems form one component of the grated group of engineered systems used at landfills to achieve environmentally land disposal of MSW. Other components include liner systems, daily and rmediate cover systems, leachate collection and removal systems, gas collection removal systems, and surface-water management systems. The general layout hese systems (excluding the intermediate cover system) at a landfill is shown in ure 1.

[1]GeoSyntec Consultants, 1100 Lake Hearn Drive, NE, Atlanta, GA 30342.
[2]GeoSyntec Consultants, 1004 East 43rd Street, Austin, TX 78751.

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LANDFILL FINAL COVER SYSTEMS 219

Figure 1. General layout of engineered systems used for liquid and gas containment/collection at MSW landfills.

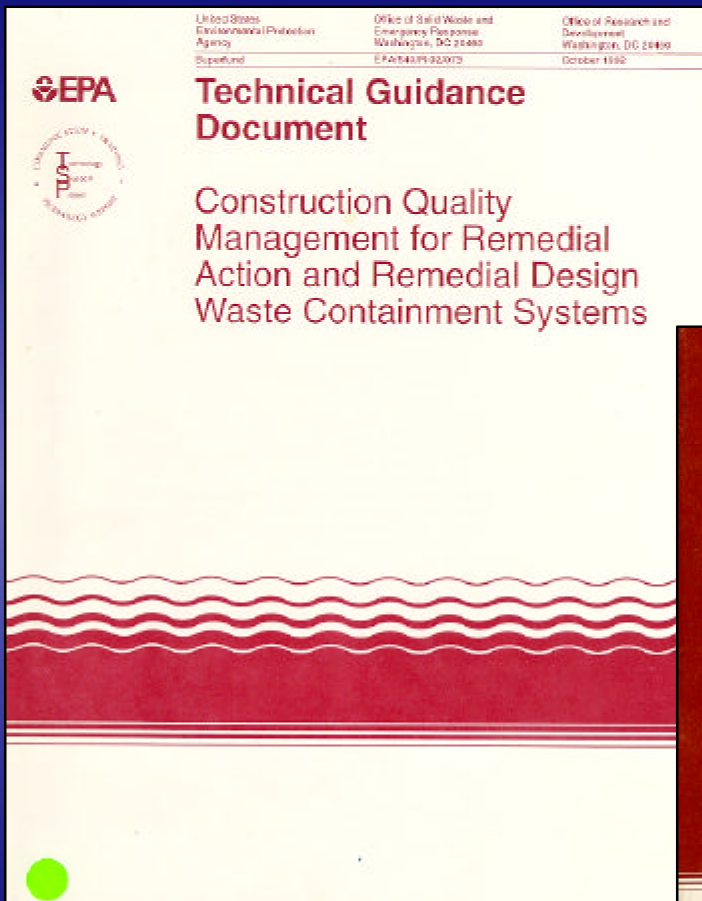
The principal functions of a landfill final cover system are:

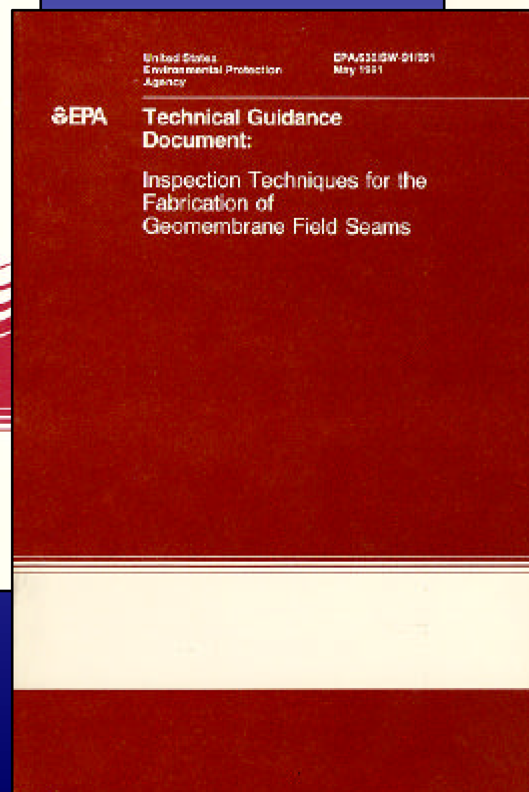
- minimize water and air infiltration into the landfill;
- minimize gas migration out of the landfill;
- serve as a system for control of odors, disease vectors, and other nuisances; and
- serve as a component of the landfill surface-water management system.

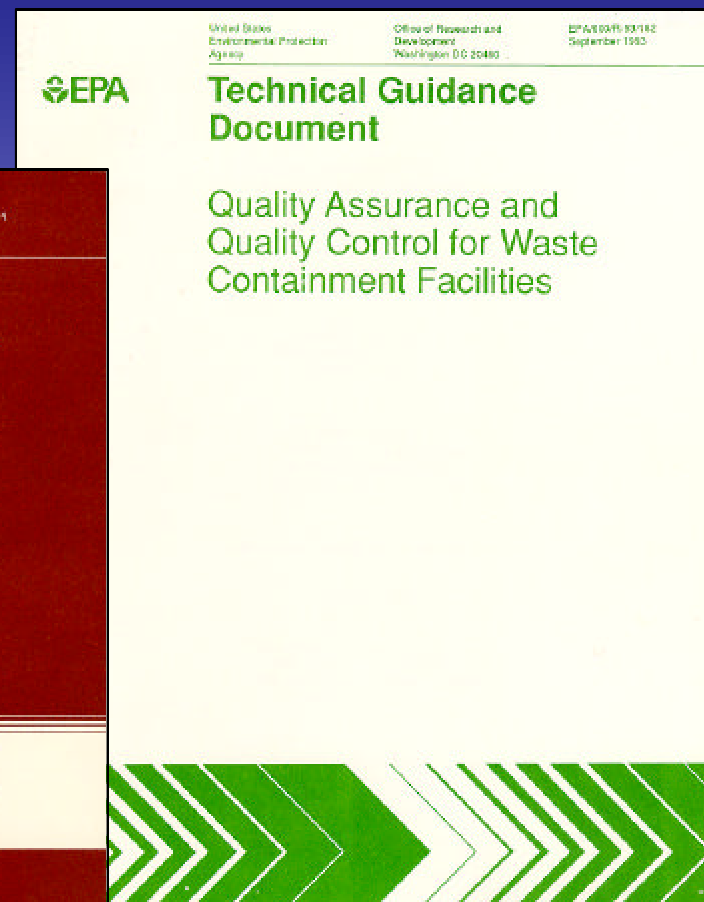
The focus of this paper is on "conventional" final cover systems consisting of a series of soil and geosynthetic layers. Typically, these systems contain hydraulic barrier layers overlain by drainage and surface layers. Alternative final cover systems, including, for instance, monolithic covers, covers incorporating capillary barriers, and covers incorporating cobble surface layers, are applicable to limited specific design applications, particularly certain applications in arid environments. In these environments, it is difficult to maintain the required moisture content of soil barrier layers during construction, the soil barrier layers are susceptible to desiccation cracking, the surface vegetation is stressed by lack of available water, and the surface layer is susceptible to erosion. The authors are aware of field studies to evaluate the performance of alternative cover systems. Studies are currently underway at a number of locations, including sites near El Paso, Texas, Albuquerque, New Mexico, and Richland, Washington. Due to page-limit constraints, these alternative cover systems are not addressed in this paper.

CONSTRUCTION GUIDELINES & QA/QC

CONSTRUCTION QUALITY CONTROL/ASSURANCE
PROCEDURES ARE WELL ESTABLISHED





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CONSTRUCTION GUIDELINES & QA/QC

- Compacted Clay Liner (CCL)
- Geosynthetics
  - Geosynthetic Clay Liner (GCL)
  - Geomembrane (GM)
  - Geonet (GN)
  - Geotextile (GT)
- Sand Drainage Layer
- Penetrations
- Test Fills

COMPACTED CLAY LINER QA/QC

- Borrow Source Assessment
- Classification Testing
- Moisture & Density Testing
- Hydraulic Conductivity Testing
- Placement

COMPACTED CLAY LINER QA/QC

BORROW SOURCE ASSESSMENT

ROCKY MOUNTAIN ARSENAL BASIN F

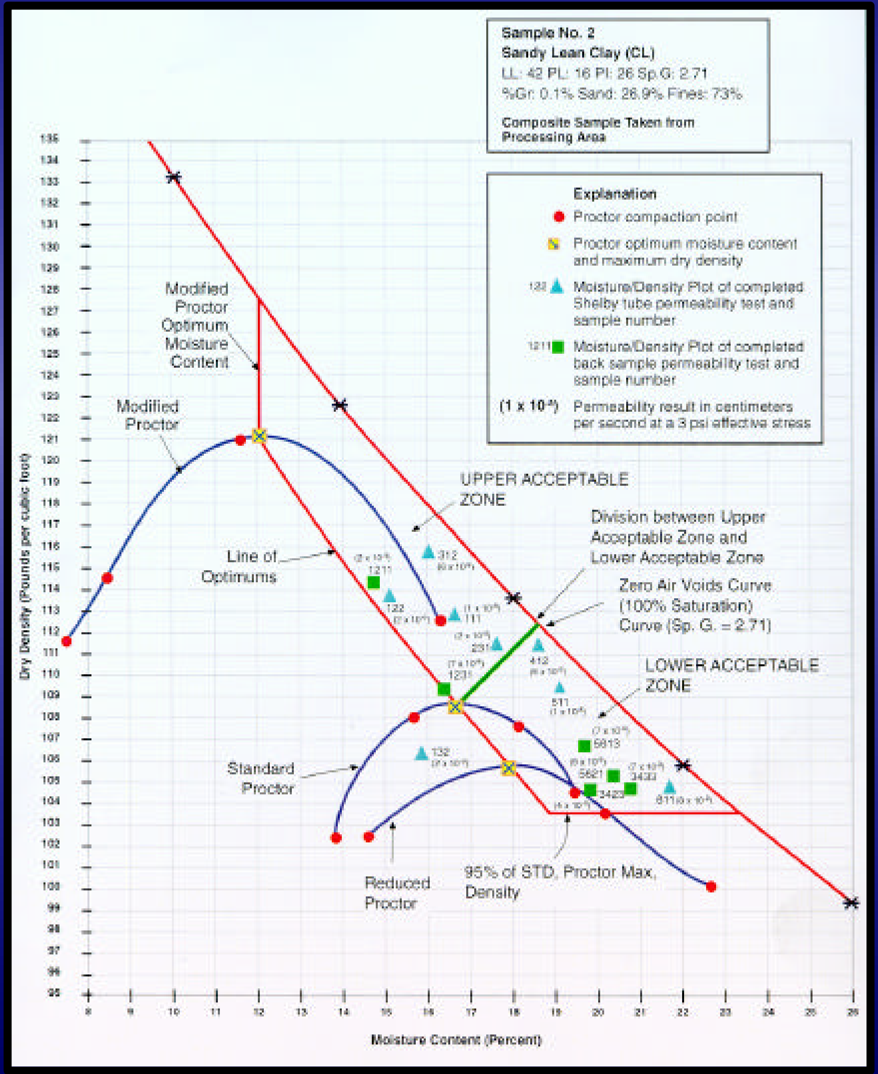
COMPACTED CLAY LINER QA/QC

PONDS CREATED FROM BORROW AREA

NEW LYME LANDFILL

COMPACTED CLAY LINER QA/QC

MOISTURE/DENSITY CURVE AND HYDRAULIC CONDUCTIVITY TESTING



COMPACTED CLAY LINER QA/QC

PLACEMENT

- Classification Testing
- Lift Thickness
- Compaction Equipment
- Scarification
- Repair of Voids
- Prevention of Desiccation or Freezing
- Excess Surface Water

COMPACTED CLAY LINER QA/QC

PLACEMENT -

CLASSIFICATION TESTING

- Mechanical Analysis (ASTM D 422)
- Atterberg Limits (ASTM D 4318)
- Classification (ASTM D 2487)

COMPACTED CLAY LINER QA/QC

PLACEMENT - MOISTURE, DENSITY, & HYDRAULIC CONDUCTIVITY TESTING

- **Moisture Content**
  - Oven (ASTM D 2216)
  - Microwave (ASTM D 4643)
  - Nuclear (ASTM D 3017)
- **Density**
  - Sand-Cone (ASTM D 1556)
  - Rubber Balloon (ASTM D 2167)
  - Nuclear (ASTM D 2922)
- **Hydraulic Conductivity (ASTM D 5084)**

COMPACTED CLAY LINER QA/QC
PLACEMENT -
IN-PLACE NUCLEAR MOISTURE/DENSITY TESTING

SOIL NUCLEAR MOISTURE/DENSITY TESTING

TESTING FORMS BECOME A PART OF THE FINAL PROJECT RECORD

COMPACTED CLAY LINER QA/QC

PLACEMENT -

HYDRAULIC CONDUCTIVITY TESTING

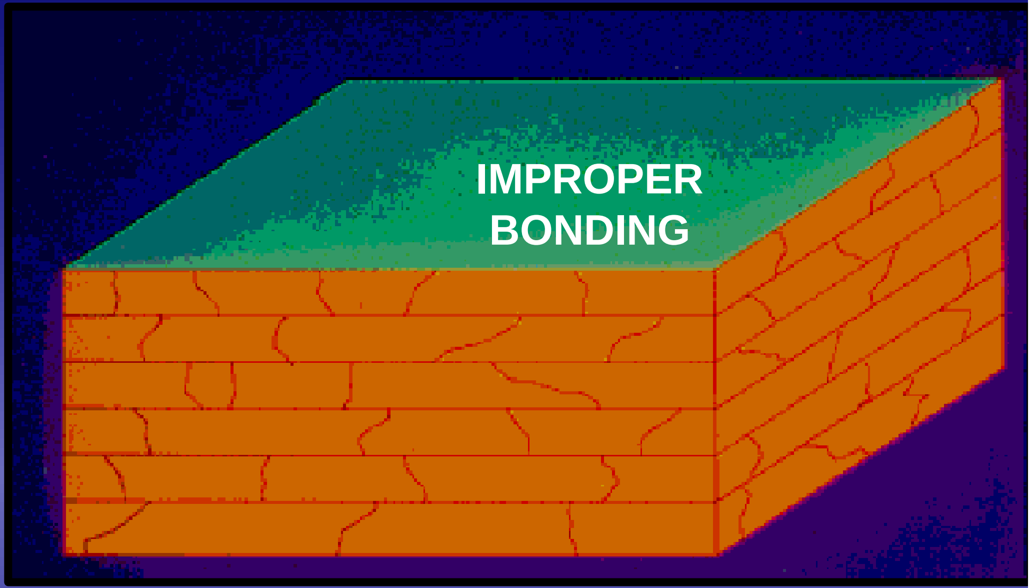
PUSHING THIN-WALLED TUBES FOR UNDISTURBED SAMPLES

LABORATORY PERMEAMETERS

HELEN KRAMER LANDFILL

COMPACTED CLAY LINER QA/QC

PLACEMENT - SCARIFICATION



SCARIFYING FOR
GOOD INTERLIFT BOND

COMPACTED CLAY LINER QA/QC

PLACEMENT -

PREVENTION OF DESICCATION OR FREEZING

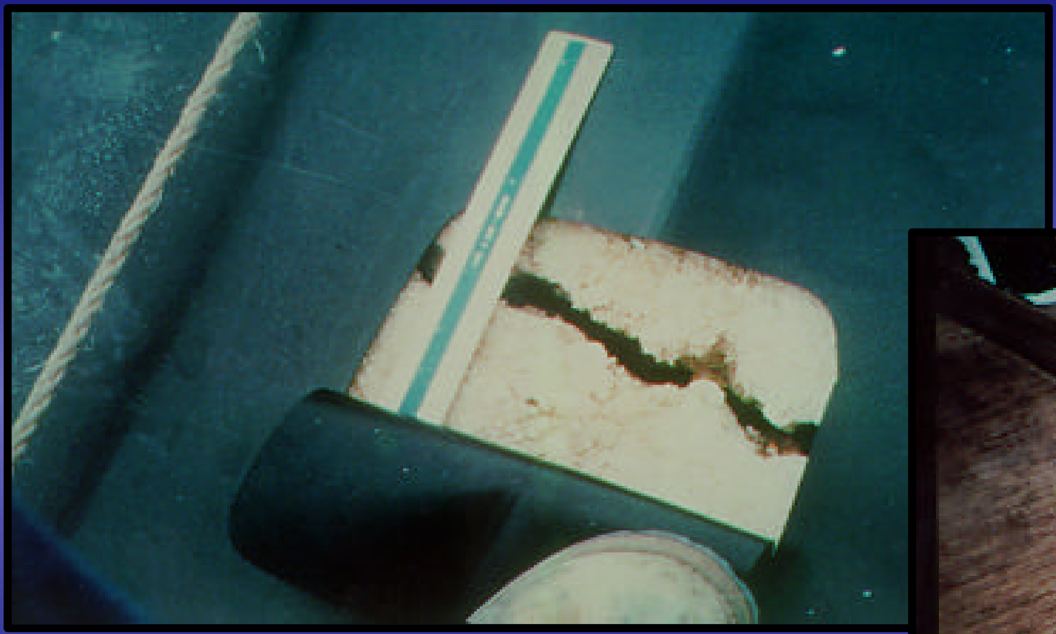
MAINTAIN CLAY MOISTURE

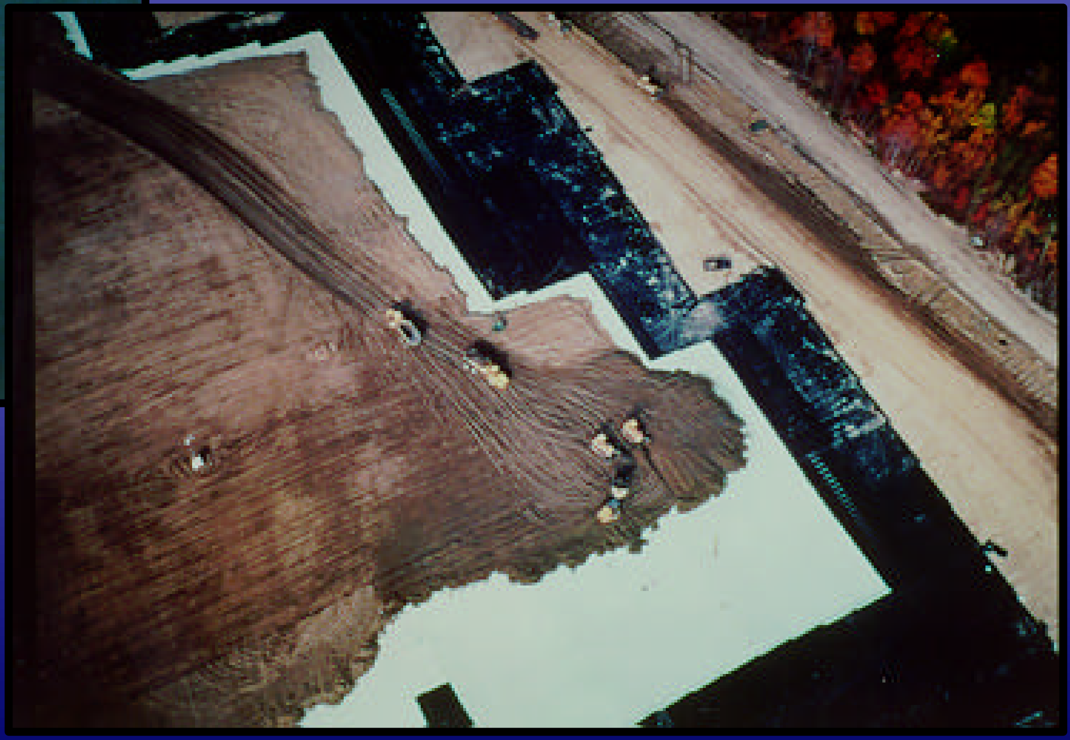
HAMILTON AFB LANDFILL 26

COMPACTED CLAY LINER QA/QC

PLACEMENT -

PREVENTION OF DESICCATION OR FREEZING





PROGRESSION OF CAP – NEW LYME LANDFILL

GEOSYNTHETIC CLAY LINER QA/QC

- Qualifications
- Drawings and Other Submittals
- Delivery, Storage, and Handling
- Properties
- Deployment
- Testing

GEOSYNTHETIC CLAY LINER QA/QC

DELIVERY, STORAGE, AND HANDLING

GEOSYNTHETIC CLAY LINER QA/QC

PROPERTIES

- Bentonite Type
  - X-Ray Diffraction (75% montmorillonite)
  - Free Swell (35 mL minimum)
- Bentonite Mass (ASTM D 5261)
- Tensile Strength (ASTM D 4632)
- Shear Strength (ASTM D 5321)
- Permeability (ASTM D 5887)

GEOSYNTHETIC CLAY LINER QA/QC

DEPLOYMENT

MARCH AFB

GEOMEMBRANE QA/QC

- Qualifications
- Drawings and Other Submittals
- Delivery, Storage, and Handling
- Properties
- Deployment
- Testing

GEOMEMBRANE QA/QC

DRAWINGS AND OTHER SUBMITTALS

- Manufacturer
  - QC Manuals/Test Results
  - Samples
  - Penetration Details
- Contractor
  - Panel Layout
  - Certified Test Results
  - As-built Drawings

GEOMEMBRANE QA/QC

PROPERTIES

- Material Type
- Texturing
- Thickness (ASTM D 1593)
- Tensile Strength (ASTM D 638)
- Puncture (ASTM D 4833)
- Multi-Axial Tensile (ASTM D 5617)

GEOMEMBRANE QA/QC

PROPERTIES - POLYETHYLENE

- **Carbon Black (ASTM D 1603)**
- **Environmental Stress Crack (ASTM D 5397)**

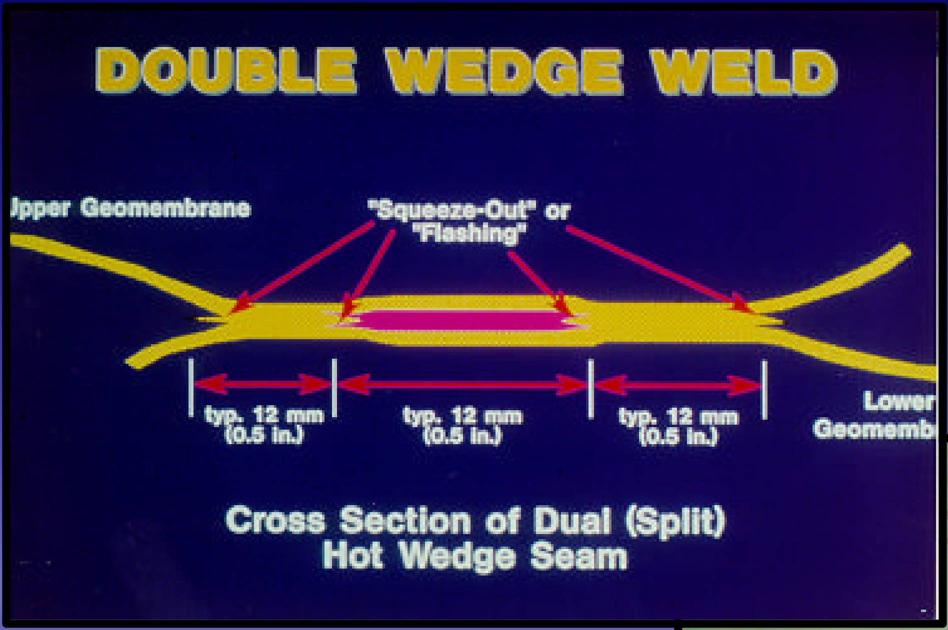
GEOMEMBRANE QA/QC

DEPLOYMENT

- Subgrade Preparation
- Parallel to Direction of Maximum Slope
- Seam Tests
  - Leaks
  - Shear Strength (ASTM D 4437)
  - Peel Strength (ASTM D 4437)
- Cover

GEOMEMBRANE QA/QC

FUSION (DOUBLE WEDGE) SEAMS



GEOMEMBRANE QA/QC

FUSION (DOUBLE WEDGE) SEAM TESTING

GEOMEMBRANE QA/QC

EXTRUSION SEAMS - GEOMEMBRANE REPAIRS

GEOMEMBRANE QA/QC

EXTRUSION SEAM TESTING

GEONET QA/QC

- Qualifications
- Drawings and Other Submittals
- Delivery, Storage, and Handling
- Properties
- Deployment
- Testing

GEONET QA/QC

PROPERTIES

- **Polymer**
  - **Density (ASTM D 1505)**
  - **Melt Index (ASTM D 1238)**
- **Carbon Black (ASTM D 4218)**
- **Tensile Strength (ASTM D 4595)**
- **Transmissivity (ASTM D 4716)**
- **Bond Properties (ASTM D 413)**

GEONET QA/QC

DEPLOYMENT

- Down slope
- Seam
  - Ties of Contrasting Color
  - Non-metallic
- Cover Soil
  - Lift Thickness
  - Equipment Restrictions

GEONET QA/QC

DEPLOYMENT

MARCH AFB

HAVERTOWN SUPERFUND SITE

GEOTEXTILE QA/QC

- Qualifications
- Drawings and Other Submittals
- Delivery, Storage, and Handling (ASTM D 4873)
- Properties
- Deployment
- Testing

GEOTEXTILE QA/QC

PROPERTIES

- Apparent Opening Size (ASTM D 4751)
- Permittivity (ASTM D 4491)
- UV Degradation (ASTM D 4355)
- Puncture (ASTM D 4833)
- Grab Tensile (ASTM D 4632)
- Trapezoidal Tear (ASTM D 4533)
- Burst Strength (ASTM D 3786)

GEOTEXTILE QA/QC

DEPLOYMENT

- Down slope
- Seam
  - Overlap
  - Type and Strength
- Cover Soil
  - Lift Thickness
  - Equipment Restrictions

SAND DRAINAGE LAYER

- Testing
- Construction

SAND DRAINAGE LAYER
TESTING

- Potential Borrow Source Investigation
  - Grain Size (ASTM D 422)
  - Hydraulic Conductivity (ASTM D 2434)
  - Carbonate Content (ASTM D 4373)

- After Placement
  - Grain Size (ASTM D 422)
  - Hydraulic Conductivity (ASTM D 2434)
  - Carbonate Content (ASTM D 4373)

SAND DRAINAGE LAYER

CONSTRUCTION

- Removal
  - Oversized Material
  - Angular Material
  - Fines
- Place Upslope
- Minimal Compaction Requirements

PENETRATIONS QA/QC

- Pipe boots factory fabricated
- Skirt should be greater than 12 inches in length
- Seaming and testing
- Stainless steel clamps and neoprene cushion
- Dry bentonite for GCLs

TEST FILLS

- Objectives
- Construction
- Testing

TEST FILLS

OBJECTIVES

- Construct full landfill cap cross section in accordance with drawings & specifications
- Model construction sequencing
- Determine material placement criteria
- Verify contractor's proposed construction equipment, materials, and procedures
- Material survivability

TEST FILLS

CONSTRUCTION

- Work plan submittal
- Construct in accordance with work plan
- Survey to monitor movement
- Carefully dismantle to note damage
- Video tape construction and dismantling
- Testing
- Post Construction report

TEST FILLS

TESTING

- Compacted Clay Liner
  - Moisture Content
  - Density
  - Hydraulic Conductivity
- Geosynthetics
  - Seam strength
  - Seam leaks

TEST FILLS

PLACE AND TEST COMPACTED CLAY LINER - SDRI

HELEN KRAMER
LANDFILL

TEST FILLS

SURVEY TO MONITOR MOVEMENT

MOYER LANDFILL

TEST FILLS
QA/QC

MOYER LANDFILL

TEST FILLS

CAREFULLY DISMANTLE TO NOTE DAMAGE

TEST FILLS

EXPOSED GEOSYNTHETICS AND SEAM TESTING

LANDFILL CASE STUDIES

LANDFILL CASE STUDIES

- Allen Harbor, RI
- MacAllister Point, RI
- Camp Pendleton, CA
- White Oak, MD
- Pax River, MD
- Bainbridge, MD
- March AFB, CA
- Hamilton AFB, CA

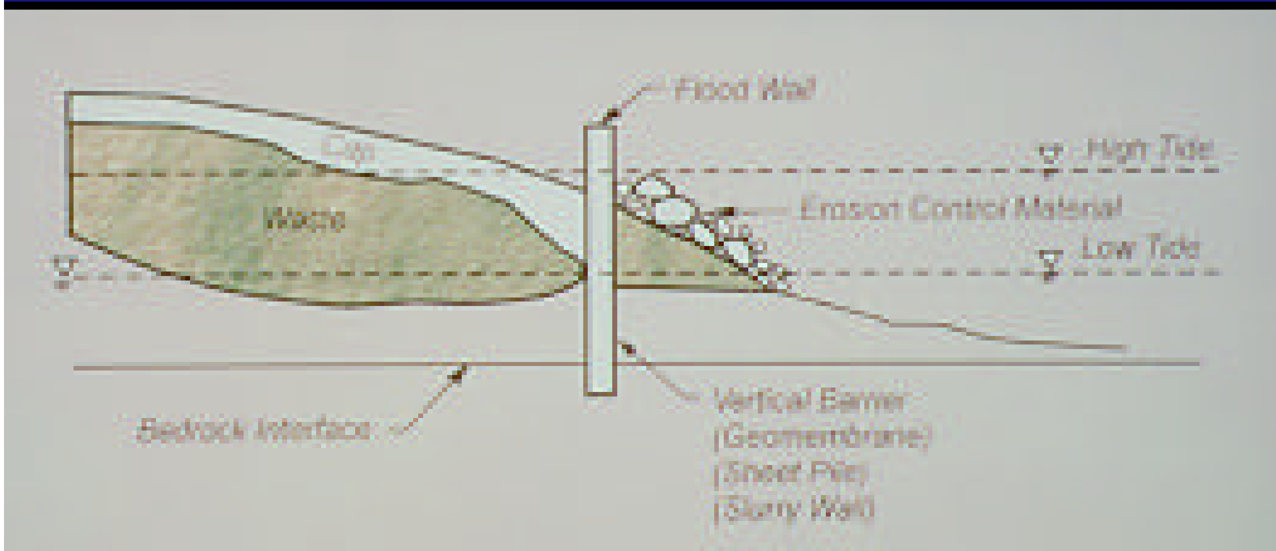
LANDFILL CASE STUDIES

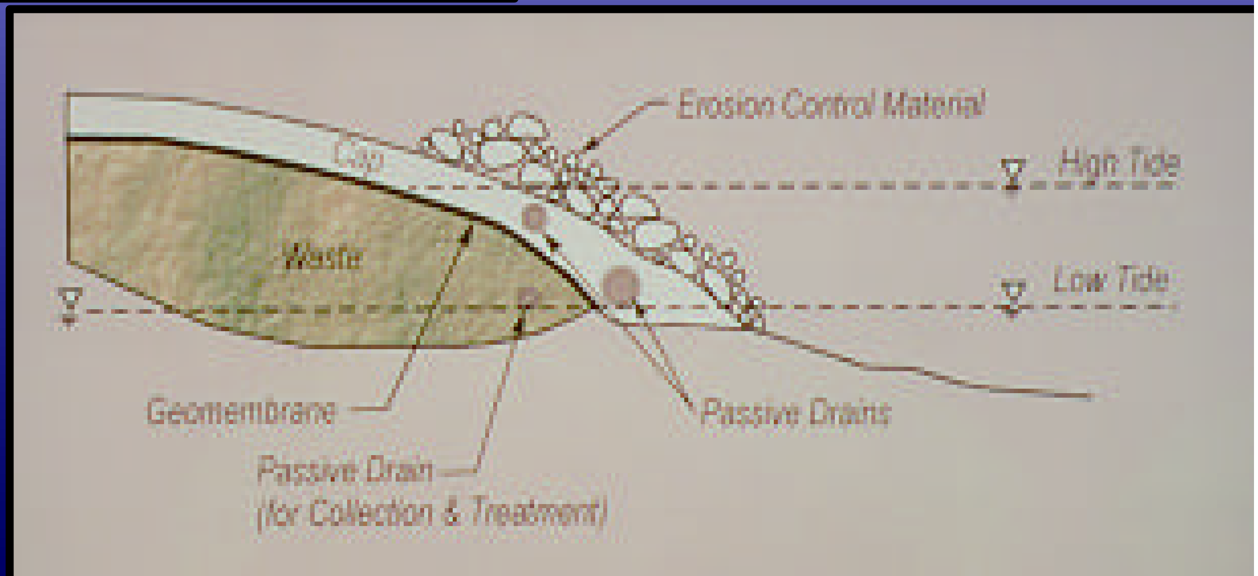
ALLEN HARBOR, RI

ALLEN HARBOR LANDFILL SHORELINE

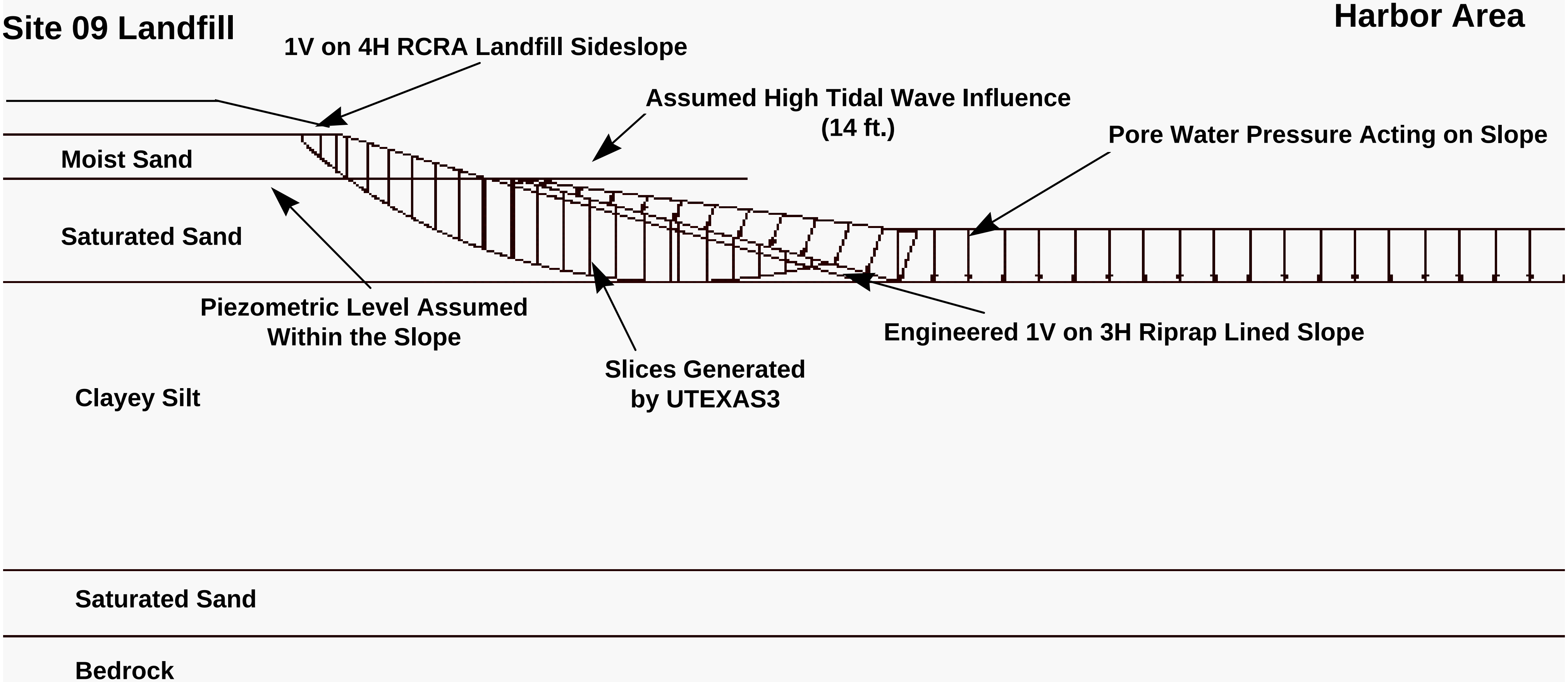
LANDFILL CASE STUDIES

SHORELINE CAP TERMINATION OPTIONS





LANDFILL CASE STUDIES
ALLEN HARBOR, RI



UTEXAS3 SLOPE STABILITY ANALYSIS
ALLEN HARBOR

LANDFILL CASE STUDIES

MACALLISTER POINT, RI

LANDFILL CASE STUDIES

CAMP PENDLETON, CA - STEEP SLOPES

BOX CANYON LANDFILL

LANDFILL CASE STUDIES

CAMP PENDLETON, CA - BALANCE CUT/FILL USING WASTE MATERIAL

BOX CANYON LANDFILL

LANDFILL CASE STUDIES

WHITE OAK, MD - STEEP SLOPES

LANDFILL CASE STUDIES

WHITE OAK, MD - UXO

LANDFILL CASE STUDIES

PAX RIVER, MD

DEVELOP ON-SITE BORROW AREAS

PAX RIVER LANDFILL

SIEVING OVERSIZED MATERIAL

PAX RIVER LANDFILL

LANDFILL CASE STUDIES

BAINBRIDGE, MD - CHANNEL FAILURE

BAINBRIDGE RUBBLE LANDFILL

LANDFILL CASE STUDIES

BAINBRIDGE, MD - EXIT CHANNEL FAILURE

BAINBRIDGE RUBBLE LANDFILL

LANDFILL CASE STUDIES

BAINBRIDGE, MD - SILT FLOW

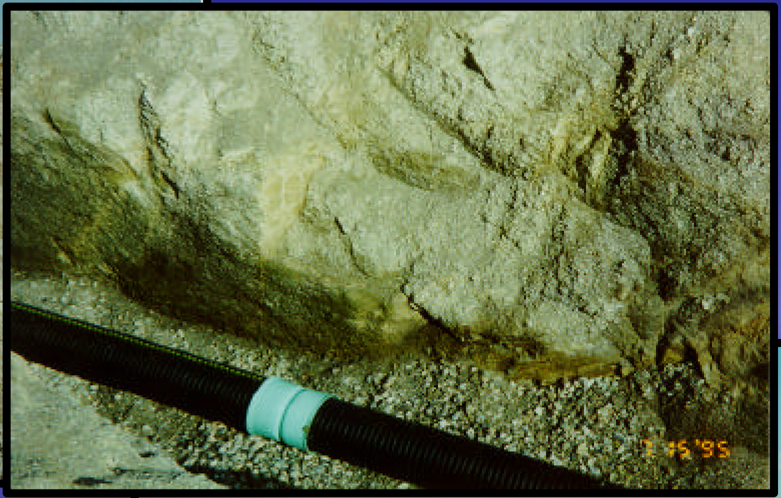
BAINBRIDGE OLD LANDFILL

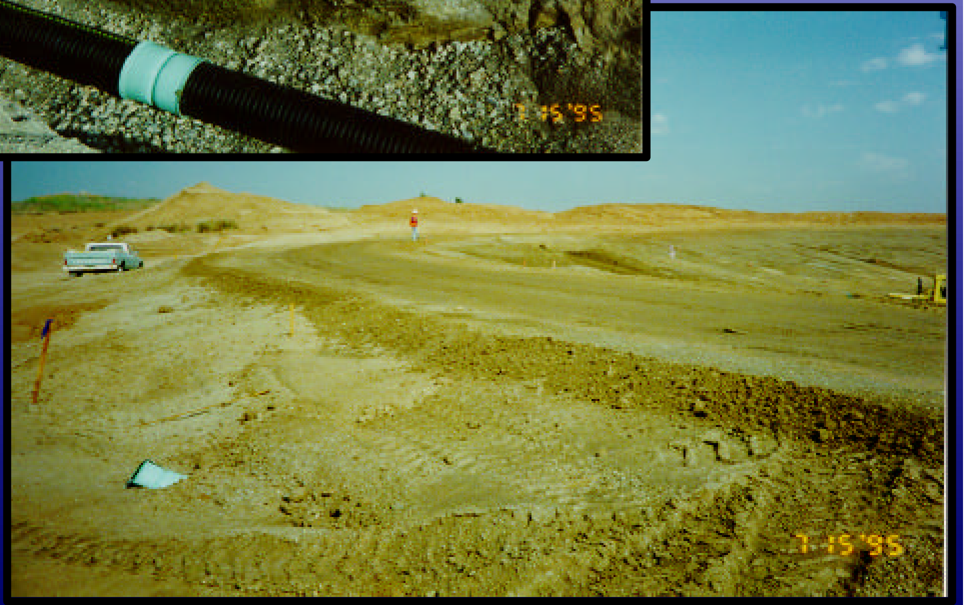
LANDFILL CASE STUDIES

MARCH AFB, CA - CAMU

LANDFILL CASE STUDIES

MARCH AFB, CA - CAMU





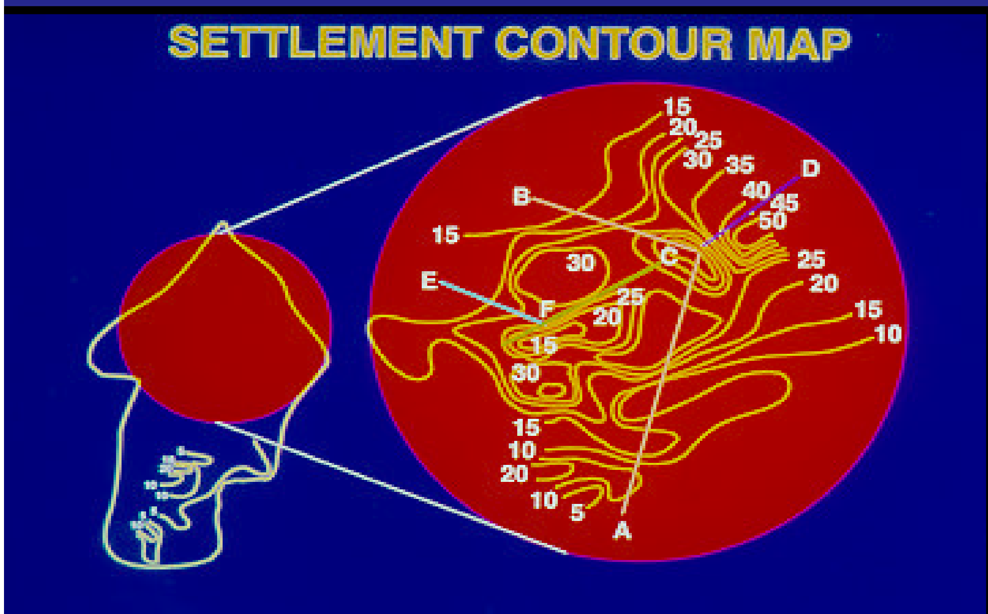
GROUNDWATER SEPARATION/CONTROL

LANDFILL CASE STUDIES

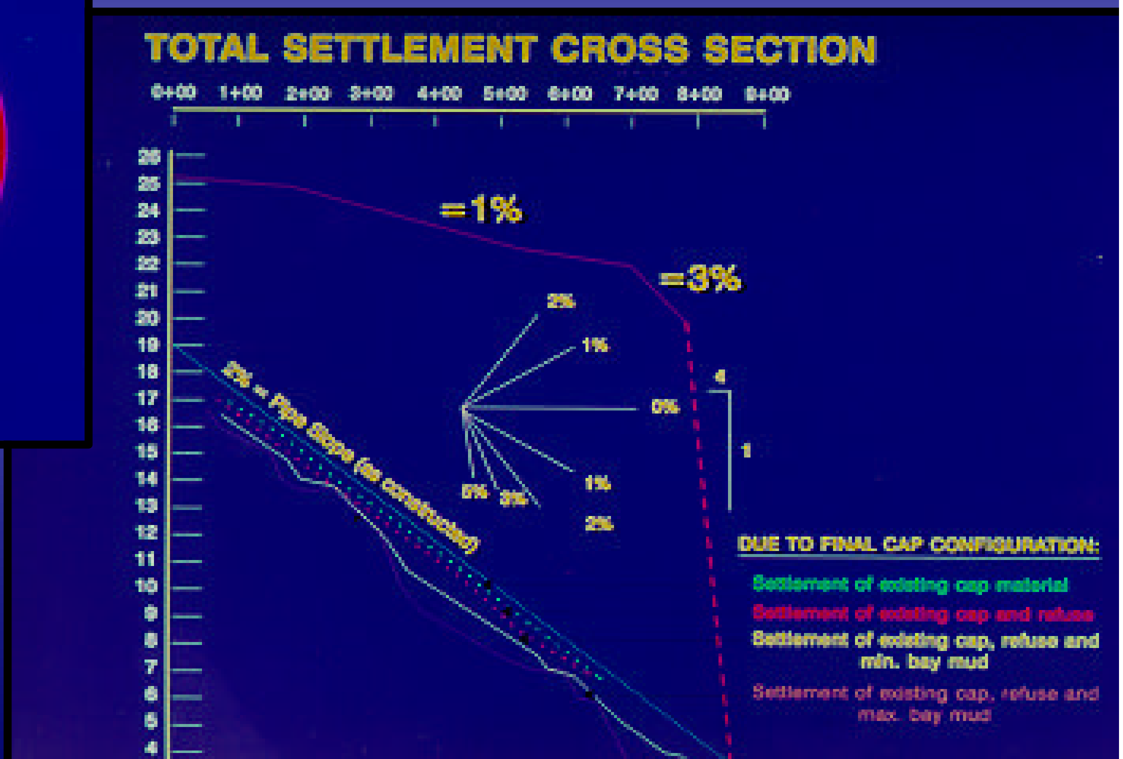
HAMILTON AFB, CA - CLIMATE

LANDFILL CASE STUDIES

HAMILTON AFB, CA - DESIGN OF INTERNAL DRAINAGE



HAMILTON AFB LANDFILL 26



LANDFILL CASE STUDIES

HAMILTON AFB, CA - SURFACE DRAINAGE / EROSION CONTROL

SILT FENCE - HAMILTON AFB LANDFILL 26

O&M ISSUES

O&M ISSUES

- Inspections
- Repairs
  - Final Cover System
  - Surface Water Management System
  - Revegetation
- System Management
  - Leachate
  - Landfill Gas

O&M ISSUES

- Environmental Monitoring Systems
  - Groundwater
  - Landfill Gas
  - Leachate
  - Storm Water
- Mowing
- Security

COST ANALYSIS / COMPARISONS

COST ANALYSIS/COMPARISONS

CONSTRUCTION COST DATA

Size (acres)	RCRA C	RCRA D
	($1,000/acre)	
< 5	1,000	150
5-20	300	100
> 20	200	75

COST ANALYSIS/COMPARISONS

O&M COST DATA

- Assumptions:
  - 10-acre Subtitle D cap
  - 30 years O&M
  - Inflation rate 3 percent
  - Passive Gas Venting System
  - No Leachate Management System
  - Monitor
    - Groundwater
    - Landfill gas
  - 3-acre repair in year 16

COST ANALYSIS/COMPARISONS

O&M COST DATA

Item	Low	High
Total Annual Costs	274,000	975,000
Repair	7,000	28,000
Post-Closure Certification	$ 15,000-35,000	$ 100,000-236,000
Total Cost	$296,000-316,000	$1,103,000-1,239,000

Source: Nickodem, Andrew F., Vladic, David S., and Menoff, Steven D., *Landfill Closure and Post-Closure Future Costs Not To Be Forgotten*, Waste Age, April 1996, p. 57-72.

SUMMARY

- Capping will continue to be a viable cost-effective remediation option.
- All capping alternatives should be evaluated.
- Good cap designs should incorporate innovative technologies.

SUMMARY

- Cap construction failures are costly
-
-
- O&M costs must be recognized